ATTACHMENT F

James River Alternatives Analysis

June 23, 2005

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in cooperation with the
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EXECUTIVE SUMMARY

The existing Virginia Water Quality Standards regulation (9 VAC 25-260-10 and 20) designates all waters for "*the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them*" and requires that substances "*which nourish undesirable or nuisance aquatic plant life*" will be controlled (9 VAC 25-260-20). Existing implementation of these narrative requirements did not prevent the tidal James River from being listed as 'impaired' under the Clean Water Act 303(d). The impairments in the tidal James River are tied to eutrophication.

The *Chesapeake 2000* Agreement specifies a goal to remove the Bay from the impaired waters list by 2010. To that end, a need for appropriate water quality standards was identified in order to define accurate water quality goals for assessment. The Virginia State Water Control Board adopted numerical criteria for dissolved oxygen, water clarity and submerged aquatic vegetation and a narrative criterion for chlorophyll *a* for the Chesapeake Bay and its tidal tributaries to drive nutrient and sediment reduction measures. These amendments are all based on recommendations from the U.S. EPA *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and its Tidal Tributaries,* April 2003 and *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability,* October 2003 (and their 2004 addendums).

However, the best information available indicates that the nutrient impairment in the tidal James River will not be sufficiently addressed by the actions taken to attain dissolved oxygen or clarity criteria. From past experience, it is questionable whether a narrative criterion alone will provide the water quality protection needed in James River. Therefore, it was determined by U.S. EPA and VA Department of Environmental Quality (DEQ) that numerical criteria for chlorophyll *a* needs to be applied to the tidal James River to quantify the water quality conditions necessary for the protection already required by the narrative criteria within the existing Virginia Water Quality Standards Regulation. EPA also strongly encourages numerical chlorophyll *a* criteria when there are existing nutrient related impairments and the impairments will likely persist after nutrient and sediment reductions are made in order to remove dissolved oxygen or water clarity related impairments. This is the case in the tidal James River.

Because of scientific and economic impact concerns raised about the numerical chlorophyll *a* criteria during the public comment process, the VA DEQ along with the U.S. EPA Chesapeake Bay Program Office committed to investigate various cap load allocation scenarios for the tidal James River and to do an analysis to see if different cap load allocations could provide equivalent environmental benefits with much lower economic impacts to localities before adopting these numerical chlorophyll *a* criteria. To best accomplish this evaluation, the Chesapeake Bay Eutrophication Model was used to simulate a range of nutrient load scenarios and associated chlorophyll *a*, water clarity and submerged aquatic vegetation changes expected to occur in the tidal James River.

Ultimately, thirteen scenarios were evaluated. Nine management scenarios assessed loadings and concentrations ranging from 1985 conditions through E3 (everything, everybody, everywhere). In addition, four scoping scenarios were tested where nutrient concentrations varied in the James Basin but sediments loadings were kept low.

A summary of the findings include:

- Thirteen model simulations captured anticipated responses of chlorophyll, water clarity and submerged aquatic vegetation (SAV) under wide ranges of loadings reductions across ten years of varying hydrology: nitrogen (46.9-15.2 million pounds), phosphorus (8.51-2.83 million pounds) and sediment (1.28-0.79 million tons).
- The tidal fresh James River displayed the highest estimated summer chlorophyll *a* concentrations of all the Chesapeake Bay Program segments in the 1985 Reference Scenario and the second highest summer average concentration in the 2002 Assessment Scenario; however, these seasonal ten year average concentrations should not be used to measure attainment of the proposed chlorophyll *a* criteria.
- The greatest reductions in chlorophyll *a* concentrations for the tidal James River were associated with the largest nutrient reductions such as Tier 3, Virginia Tributary Strategy and Scoping Scenario D. The following summarizes chlorophyll *a* attainment in tidal James River segments responding to a range of nutrient reductions:
    - Lower tidal fresh (JMSTF1) was responsive during both spring and summer, but greatest during the summer. Spring chlorophyll *a* attainment was between 12 and 22 μg/L for TN loads between 22 and 37 million pounds. Summer chlorophyll *a* attainments ranged from 20 μg/L (loads between 22 and 26 million pounds of TN) to above 30 μg/L of chlorophyll *a* (34 to 47 million pounds of TN).
    - The oligohaline (JMSOH) chlorophyll *a* attainment changed between seasons with the spring having lower attainment levels than summer over the range of TN loads. For example, spring chlorophyll a attainment was from 11 to 20 μg/L between 22 and 38 million pounds of TN while summer chlorophyll *a* attainment levels ranged from 21 to 25 μg/L for the same loadings.
    - The mesohaline (JMSMH) was most responsive during spring with chlorophyll *a* attainments between 11 and 13 μg/L below TN loads of 30 million pounds and above 15 μg/L for TN loads greater than 30 million pounds. Summer chlorophyll *a* attainments were less than 12 μg/L across the range of TN loads.
    - The polyhaline (JMSPH) showed a similar pattern as the oligohaline with spring chlorophyll *a* attainments less than 14 μg/L below TN loads of 30 million pounds and above 15 μg/L for TN loads greater than 30 million pounds. Again, summer chlorophyll *a* attainment was less than 10 μg/L across the range of TN loads for this segment.

- While nutrients were the primary driver of chlorophyll *a* concentrations and sediments the driver for water clarity improvements, almost all segments showed an increase in submerged aquatic vegetation (SAV) acreage from combined nutrient and sediment reductions.
- While the Eutrophication Model could not be used to quantify exactly how each scenario (each with its own estimated chlorophyll *a* concentrations) might impact the aquatic food web directly, it was used to estimate how much lower chlorophyll *a* concentrations should get in the tidal James River in response to key scenarios. Based on basic principals of ecology, published scientific research, and this alternatives analysis, several conclusions were reached:

- Segments characterized as “impaired” consisted of imbalanced algal communities dominated by “undesirable” and “nuisance” forms with risk of algal blooms greater then 50%.
- As chlorophyll *a* concentrations approached “least-impaired” or “reference” concentrations, algal communities would be more “balanced” with fewer “undesirable” and “nuisance” forms and risks of algal blooms reduced to less then 10%.
- Management scenarios Virginia Tributary Strategy and Virginia Tributary Strategy Alternative were closest to “reference” conditions.
- Two independent scientific reviews by Virginia Institute of Marine Sciences (VIMS) and Virginia Commonwealth University (VCU) confirmed that the proposed chlorophyll *a* concentrations do not pose a threat to the long-term productivity of finfish and shellfish populations in James River.
- Monitoring data from a station in the lower tidal fresh found 72% of the summer chlorophyll *a* concentrations in the lower tidal fresh James River were at levels associated with the risk of short term adverse health outcomes.
- This alternatives analysis indicates that significant improvements could be obtained under the cap loads associated with the management scenarios Virginia Tributary Strategy, Virginia Tributary Strategy Alternative, and Scoping Scenario D. However, other scenarios such as Tier 2, Option 2 and Scoping B, also showed improvements in certain segments. This indicates that additional investigation of a combination scenario would prove beneficial.

TABLE OF CONTENTS

EXECUTIVE SUMMARY I

INTRODUCTION 1

CHAPTER 1: BACKGROUND 3

CHAPTER 2: MANAGEMENT AND SCOPING SCENARIOS 7

CHAPTER 3: SPRING AND SUMMER MEAN CHLOROPHYLL A FOR ALL BAY SEGMENTS AND JAMES CFD ANALYSIS 15

CHAPTER 4: SUBMERGED AQUATIC VEGETATION RESPONSE TO MANAGEMENT AND SCOPING SCENARIOS 43

CHAPTER 5: RELATING CHLOROPHYLL CONCENTRATIONS AND STANDARD NITROGEN LOADS 49

CHAPTER 6: QUESTIONS RELATED TO THE ALTERNATIVES ANALYSIS FOR CHLOROPHYLL-A STANDARDS – WILLIAMS SB 811 55

APPENDIX A 65

APPENDIX B 71

APPENDIX C 79

INTRODUCTION

In 2004 – 2005 Virginia proposed numerical water quality criteria for chlorophyll *a* applicable to the tidal James River. These criteria were part of a larger rulemaking that included new designated uses and nutrient – and – sediment related criteria for Chesapeake Bay and its tidal tributaries. As a result of the public comment process for that rulemaking, the VA Department of Environmental Quality along with the U.S. EPA Chesapeake Bay Program Office committed to investigate alternative cap load allocation scenarios for the James River to see if different cap load allocations could provide equivalent environmental benefits with much lower economic impacts to localities before adopting these numerical chlorophyll *a* criteria. This document describes that analysis.

The analysis is laid out in six Chapters. Chapter 1 provides the background of Virginia's water quality regulatory history related to the current rulemaking. Descriptions of the thirteen management and scoping scenarios used in this analysis are included in Chapter 2. These scenarios are the 1985 Reference, 2002 Assessment, Tier 1, Tier 2, Tier 3, Virginia Tributary Strategy, Virginia Tributary Strategy Alternative, Option 4, and E3 Scenario as well as four scoping scenarios. Chapter 3 contains model simulated spring and summer mean chlorophyll *a* concentrations for all Bay segments and model simulated attainment levels of the proposed numerical chlorophyll a criteria for all the tidal James River segments. Chapter 4 is an analysis of model simulated James River light attenuation levels. Model simulated water quality criteria attainment and estimated acreages of restored SAV are examined as well. Chapter 5 contains plots of chlorophyll *a* concentrations and estimated chlorophyll *a* criteria attainment related to James total nitrogen loads. For all of these analyses, both spring or summer seasons are used, with spring season set at March through May while a summer season consists of July through September. The appropriate SAV growing seasons are used for the clarity attainment criteria. Chapter 6 contains a response to questions raised during 2005 General Assembly with the introduction of *SB 809 (Williams)* and the *Alternative Analysis for Chlorophyll a Standards* (see Appendix A).

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Chapter 1: BACKGROUND

The existing Virginia Water Quality Standards regulation (9 VAC 25-260-10) designates all waters for *"the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them."* The intent of the use designation is to maintain balanced populations of all aquatic life from the base of the food chain (algae) up to commercial and recreational fishes.

Virginia's existing narrative criteria in the Water Quality Standards further require that substances *"which nourish undesirable or nuisance aquatic plant life"* will be controlled (9 VAC 25-260-20). To meet that requirement, Virginia adopted the Nutrient Enriched Waters (9 VAC 25-260-330-350) and Policy for Nutrient Enriched Waters (9 VAC 25-40) in 1988. These existing regulations also recognized that nutrients were contributing to undesirable growths of aquatic plant life, classified waters as nutrient enriched and imposed phosphorus limits on discharges to waters classified as nutrient enriched. The Chesapeake Bay and its tidal tributaries were all classified as nutrient enriched under these regulations. Chlorophyll *a* was also recognized in the Nutrient Enriched Waters sections of the regulation as an indicator of nutrient enrichment.

Virginia's existing Water Quality Standards narrative criteria have been in place since 1988. However, the tidal James River has the most 'unbalanced' phytoplankton community compared to Virginia's other tidal waters with numerous observations of over-abundances of 'undesirable' plant life. Also, in May 1999, the tidal James River was included on the 303(d) impaired waters list due to violations of the general narrative criteria and nutrients.

Waters included on the impaired waters list require the development of a total maximum daily load (TMDL). The *Chesapeake 2000* Agreement specifies a goal to remove the Bay and its tidal tributaries from the impaired waters list by 2010. Thus, the development of a TMDL has been postponed until 2010 anticipating the Bay watershed states can achieve water quality standards by that time thereby making a TMDL unnecessary. To that end, a need for appropriate water quality standards was identified in order to define accurate water quality goals for assessment.

After the 303(d) impairment listing, it was clear to the Virginia Department of Environmental Quality (DEQ) that continuing with a narrative criteria approach to the tidal James River ecosystem will not provide the technical basis for implementing the necessary nutrient loading reduction actions needed to restore balance to that ecosystem. Narrative criteria are difficult to implement and enforce. Therefore, it has been recommended by the U.S.EPA that the Commonwealth needs numerical criteria for chlorophyll *a* applied to the tidal James River to quantify the water quality conditions necessary for the protection already required by the use designation and narrative criteria within the existing Virginia Water Quality Standards Regulation.

To further support the need for numerical chlorophyll *a* criteria, U.S. EPA strongly encourages numerical chlorophyll criteria when there's existing nutrient related impairment and that impairment will likely persist after nutrient and sediment reductions are made in order to remove dissolved oxygen or water clarity impairments. This is the case in the tidal James River.

In November 2004, DEQ proposed for public comment five new use designations and nutrient and sediment related numerical and narrative criteria for the Chesapeake Bay and its tidal tributaries. These amendments are all based on recommendations from the U.S. EPA *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and its Tidal Tributaries,* April 2003 and *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability*, October 2003 and their 2004 addendums. The Department also proposed numerical chlorophyll *a* criteria for the tidal James River. In March 2005, all U.S. EPA recommended use designations and numerical criteria were adopted into State Water Quality Standards by the Virginia State Water Control Board except for the numerical chlorophyll *a* criteria for the James River and special dissolved oxygen criteria for the Mattaponi and Pamunkey Rivers.

The postponement was necessary to respond to many technical comments received from the Virginia Municipal Wastewater Agencies (VAMWA) on the numerical chlorophyll *a* criteria. In addition, the technical comments prompted Senator Williams to offer SB 811 to the General Assembly. The bill would have required an analysis of the benefits, detriments, and the economic and social costs associated with alternatives when the State Water Control Board considered adoption of a chlorophyll standard. While the bill remained in the Committee of Agriculture, Conservation and Natural Resources, the DEQ committed to investigate alternative chlorophyll *a* criteria or load allocation scenarios for the James River, which could provide equivalent environmental benefits with much lower economic impacts to localities before adopting these numerical chlorophyll *a* criteria.

Based on various correspondences, a list of scenarios were developed with a focus on "isolation of James River" and "Focus on Nutrients, not Sediment" (Pomeroy 2005a,b). While impossible to address all their concerns with the tools at our disposal, both DEQ and USEPA staff feel all of the critical issues are addressed in the following report. To best accomplish this evaluation, the Chesapeake Bay Eutrophication Model was used to simulate a range of nutrient load scenarios and associated chlorophyll *a* concentrations and water clarity (SAV acreage) changes expected to occur in the tidal James River. VAMWA requested one scenario representative of existing (2002) conditions, one of the Virginia 2004 tributary strategy and three to test various levels of nutrient removal where sediment load were kept low (Table 1). Ultimately, thirteen scenarios were evaluated. Loadings and concentrations ranged from 1985 conditions through E3 (everything, everybody, everywhere) and four scoping scenarios where nutrient concentrations varied in the James Basin but sediments loadings were kept at 2005 tributary strategy levels. These model scenarios are described in Chapter 2. Resulting chlorophyll *a* concentrations and levels of estimated chlorophyll *a* attainment are presented in Chapter 3. As requested by VAMWA, estimated attainment of a range of alternative incremental chlorophyll *a* criteria concentrations for each scenario are presented (Pomeroy 2005b).

There are other non-regulatory, regulatory and legislative actions that are related to this analysis. Before criteria or impairments were identified, the U.S. EPA Chesapeake Bay Program, along with the Bay states, established non-regulatory Tributary Strategies for each basin to improve living resources in the watershed. These strategies were updated in 2005 and contain agreed upon nutrient cap load allocations for each basin. These goals are voluntary agreements but were based on EPA's recommendations for water quality standards for the Chesapeake Bay and its tidal tributaries. These are the same standards now in regulatory development in Virginia.

Table 1.1. List of alternative model scenarios proposed by VAMWA in the James Alternatives Analysis

Sce-nario	Descrip.	Regional nutrient removal assumptions			James sediment removal assump.	Northern Bay* nutrient removal	New or existing scenario	Scoping scenarios
		AFL	TF	LE				
1	2000 TS (rev.)	1996 Progress	BNR equivalent	1996 Progress	VATS 2005	2003 Cap Allocation	New	A
2	2002*** Progress	2002 Progress	2002 Progress	2002 Progress	2002 Progress	2002 Progress	Existing	2002 Progress
3	Intermed. 1	2002 Progress	Tier 2	2002 Progress	VATS 2005	2003 Cap Allocation	New	B
4	Intermed. 2	Tier 1	Tier 1	Tier 1**	VATS 2005	2003 Cap Allocation	New	C
5	VATS 2005	VATS 2005	VATS 2005	VATS 2005	VATS 2005	2003 Cap Allocation	Existing	VATS 2005

Source: Pomeroy 2005a

* Northern Bay is represented by the Rappahannock River and north.
** Tier 1 reflects performance of 8 mg/L TN at existing BNR facilities and year 2000 loads at non BNR plants.
*** 2002 Progress was later renamed 2002 Model Assessment or 2002 Assessment hereafter (refer to Chapter 2)
AF L= Above fall line James River .Basin
TF = Tidal fresh water region – tidal river segment JMSTF
LE = Lower estuary region – tidal river segments JMSOH, JMSMH, and JMSPH.

As previously mentioned, DEQ committed to consider the results of this analysis before adopting the numerical chlorophyll *a* criteria for the tidal James River (Table 1.2). To implement these criteria (and the dissolved oxygen and water clarity criteria), amendments to the Water Quality Management Planning Regulation and the Policy for Nutrient Enriched Waters are being considered. The Water Quality Management Planning Regulation specifies nitrogen and phosphorus loading allocations for significant dischargers in the Chesapeake Bay watershed. The final chlorophyll *a* criteria, along with the other new criteria, will dictate the nutrient and sediment loading reductions necessary within the James basin. The Policy for Nutrient Enriched waters (renamed Regulation for Nutrient Enriched Waters) specifies technology based nutrient limits for certain dischargers. Also, the 2005 Virginia General Assembly established a watershed general permit and point source nutrient trading program to assist in meeting the load allocations for the Chesapeake Bay. The resulting regulation from that legislation will provide a cost-effective means to achieve the nutrient reductions needed to meet the assigned nutrient allocations for point source dischargers.

Table 1.2. Proposed numerical chlorophyll *a* (µg/L) criteria for tidal James River.

Segment/Season	Spring Chl *a* (µg/L)	Summer Chl *a* (µg/L)
Tidal Fresh Upper (JMSTF2)	10	15
Tidal Fresh Lower (JMSTF1)	15	20
Oligohaline (JMSOH)	15	15
Mesohaline (JMSMH)	10	10
Polyhaline (JMSPH)	10	10

Source: Virginia DEQ 2004 (revised 2005)

References:

Pomeroy, C.D. 2005a. Alternative Analysis for Chl STD. email dated February 09, 2005.

Pomeroy, C.D. 2005b. Alternative Analysis for Chl STD. email dated April 15, 2005.

Virginia Department of Environmental Quality. 2004. Virginia Department of Environmental Quality Technical Report: Chlorophyll a Numerical Criteria for the tidal James River. November 30, 2004 (revised January 12, 2005).

Chapter 2: MANAGEMENT AND SCOPING SCENARIOS

This chapter contains a description of the thirteen model scenarios used in this analysis for the tidal James River. It is separated into two sections. The first is a brief history followed by a description of the scenarios employed during this investigation. There were nine management scenarios (1985 Reference, 2002 Model Assessment, Tier 1, Tier 2, Tier 3, Virginia Tributary Strategy (VATS), Virginia Tributary Strategy Alternative, Option 4, and E3) as well as four scoping scenarios. Virginia Department of Environmental Quality along with the U.S. EPA Chesapeake Bay Program Office committed to investigate alternative chlorophyll *a* criteria for various load allocation scenarios for the tidal James River. This investigation was to assess if different nutrient cap load allocations could provide equivalent environmental benefits with much lower economic impacts to localities before adopting the proposed numerical chlorophyll *a* criteria. To best accomplish this evaluation, the Chesapeake Bay Eutrophication Model was used (Cerco and Noel 2004). The modeling framework provided projections of expected water habitat quality responses in the tidal James River under a variety of nutrient and sediment loading options.

The management scenarios were developed as part of the *Chesapeake 2000* Agreement and EPA's document for the *Regional Criteria Guidance* that included *Designated Uses and Attainability*. For example, 1985 Reference was used to establish a reference to compare other scenarios. This reference represented the entire Chesapeake Bay and its tidal tributaries in 1985 with respect to point and non-point sources as well as atmospheric loadings. The 2002 Model Assessment examined progress anticipated from reducing nutrient and sediment loadings from 1985 to 2002. The Tier 1, 2 and 3, Option 4, and E3 scenarios were developed and fully described as part of the *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability* (USEPA 2003a) and the *Setting and Allocating the Chesapeake Bay Basin Nutrient and Sediment Loads* (USEPA 2003b). The two Virginia Tributary Strategy Scenarios (VATS and VATS Alternative) were designed to assess expected water and habitat quality anticipated with local tributary strategies described in *Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for the James River, Lynnhaven and Poquoson* (Virginia 2005).

Four scoping scenarios were intended to examine different nutrient levels combined with a high level of sediment controls as defined under Virginia Tributary Strategy. However, the scoping runs were acknowledged to be unrealistic as management scenarios. For example, in the case of Scoping Scenario A, non-point source management practices for controlling sediment at the 2005 Tributary Strategy level would also reduce nutrient loads, particularly phosphorus, beyond that of the 2002 Assessment Scenario.

All of the scenario results were based on a ten-year simulation period of varying hydrology in the Chesapeake watershed with emphasis on water quality and living resource responses to tidal James River. The simulation period included the 1985 to 1994, inclusive.

DESCRIPTION OF SCENARIOS

The thirteen scenarios used in this analysis were the 1985 Reference, 2002 Model Assessment, Tier 1, Tier 2, Tier 3, Virginia Tributary Strategy (VATS), Virginia Tributary Strategy Alternative, Option 4, and E3 Scenarios and four scoping scenarios which apply high levels of sediment load reduction while exploring different levels of nutrient reductions. Table 2.1 and 2.2 lists the James nutrient and sediment loads from the watershed model for each of the thirteen scenarios of this analysis. Additional scenario documentation and watershed model description can be found in *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability* (USEPA 2003a) and *Setting and Allocating the Chesapeake Bay Basin Nutrient and Sediment Loads* (USEPA 2003b). Point source loads by basin segment for each scenario from watershed model are in Table 2.3. A description of each scenario follows with Table 2.4 outlining the basic assumptions used for nutrient and sediment loadings employed.

1985 Reference Scenario

The 1985 Reference Scenario was an estimate of the nutrient and sediment loads to the tidal Chesapeake under 1985 conditions. This scenario was used as a measure of progress since 1985, when the highest level of nutrient and sediment loads were entering the Bay. The 1985 Reference Scenario used 1985 land use, point source flows, and animal population estimates as input data. Shoreline sediment input was consistent with the year 2000 shoreline management practices.

2002 Model Assessment Scenario (VAMWA Scenario 2)

The 2002 Model Assessment Scenario (previously referred to as the 2002 Progress Scenario hereafter called 2002 Assessment) estimated nutrient and sediment loads delivered to the tidal Chesapeake under implementation of 2002 BMPs and point source loads. Estimated loads for the 2002 Model Assessment Scenario provided an assessment of current levels of nutrient and sediment load controls. This simulation used 2002 land use, point source flows, and animal population estimates as input data. Shoreline sediment input was consistent with the year 2000 shoreline management practices. It corresponds to Scenario 2 from Table 1.1.

Tier 1 Scenario

The Tier 1 Scenario assumed the current rates of implementation of nutrient and sediment controls projected to a 2010 land use, point source flows, and animal population estimates. Shoreline sediment input was consistent with the year 2000 shoreline management practices.

Tier 2 Scenario

The Tier 2 Scenario assumed an accelerated rate of implementation of nutrient and sediment controls applied to 2010 land use, point source flows, and animal population estimates as input data. All significant point sources were set at the estimated 2010 flows with nitrogen concentrations of 8.0 mg/L, and phosphorus concentrations of 1.0 mg/L or their current permit, whichever was less. Significant industrial dischargers reduce nutrient dischargers to half that of Tier 1 loads or to the permit limit, whichever was less. Shoreline sediment input was consistent with the year 2000 shoreline management practices.

Tier 3 Scenario

The Tier 3 Scenario assumed the maximum practical rate of acceleration of nutrient and sediment control implementation applied to 2010 land use, point source flows, and animal population estimates as input data. All significant point sources were set at the estimated 2010 flows with nitrogen concentrations of 5.0 mg/L, and phosphorus concentrations of 0.5 mg/L or their current permit, whichever was less. Significant industrial dischargers reduce nutrient dischargers to 80% that of Tier 1 loads or to the permit limit, whichever was less. Shoreline sediment input was consistent with the year 2000 shoreline management practices.

Virginia Tributary Strategy Scenario (VATS) (VAMWA Scenario 5)
The Virginia Tributary Strategy Scenario used the information provided by the Virginia Tributary Strategies combined with information from the Pennsylvania, Maryland, and District of Columbia tributary strategies to generate estimates of loads as close as possible to the final tributary strategies. Final tributary strategies were not available from New York, West Virginia, or Delaware and from these States the loads from the Confirmation scenario, a condition described as a "best guess" of the final tributary strategy, were used. Shoreline management was applied as specified in the Tributary Strategy, which was slightly more than a 20% reduction of shoreline loads used in Option 4.

Virginia Tributary Strategy Alternative Scenario
The Virginia Tributary Strategy Alternative Scenario applied controls of enhanced nutrient reduction on point source dischargers in the James mesohaline and polyhaline regions. Enhanced nutrient removal was set at levels of total nitrogen control at 5.0 mg/L and phosphorus at levels of total phosphorus control of 0.5 mg/L. These control levels harmonized the level of the Virginia Tributary Strategy point source discharge controls more consistently throughout the James River basin. Apart from the point source reductions in the mesohaline and polyhaline regions of the Bay this scenario was identical to the Virginia Tributary Strategy Scenario. Shoreline management was applied as specified in the Tributary Strategy, which was slightly more than a 20% reduction of shoreline loads used in Option 4 scenario described below.

Option 4 Scenario
The Option 4 Scenario assumed an overall Bay-wide load of 188 million pounds nitrogen and 13.3 million pounds phosphorus. This load was achieved by setting the basins of the Potomac and above to the Tier 3 level of loads, and the Rappahannock, York, James, and East Shore Virginia basin to their existing (1998) tributary strategy levels of nutrient reductions. Shoreline sediment reductions of 20% were from the base calibration.

E3 Scenario
The E3 Scenario has been described as " everyone, everywhere, does everything". It was based on a level of implementation that would occur if there were no constraints on costs or certain physical limitations as to the practical level of implementation of some BMPs using 2010 estimated land use. All significant point sources were set at estimated 2010 flows (industries set to 2000 flows) with nitrogen concentrations of 3.0 mg/L, and phosphorus concentrations of 0.1 mg/L or their current permit limit, whichever was less. Shoreline sediment input was consistent with the year 2000 shoreline management practices.

Scoping Scenario A (VAMWA Scenario 1)
This was the first of four scoping scenarios that focus on estimated water quality effects from different nutrient load levels while maintaining a high level of sediment reductions. Non-point source loads (including land use and animal population) of nitrogen and phosphorus were at

2002 Model Assessment Scenario levels, and non-point source sediment loads were set at the higher levels of the 2005 James Tributary Strategy load. James point source loads varied by region. In the free flowing James River watershed above Richmond, typically represented as "above the fall line" and for all regions of the tidal James but the tidal fresh, point source flows and loads were set at the level of 1996 flows and loads. For the tidal fresh region of James River, point source flows were at 1996 levels and point source loads were determined by a an assumed level of BNR control with a level of nitrogen control of 8.0 mg/L and a point source phosphorus concentration of 2.0 mg/L. Industrial loads were decreased by half their 1996 loads (representing a 1996 flow and 50% reduction in 1996 nutrient concentrations). The tidal fresh region of the James is shown in Figure 2.1. The five major regions of the James including the Tidal Fresh Upper, Tidal Fresh Lower, Oligohaline, Mesohaline, and Polyhaline are shown in Figure 2.2. Tributary Strategies were used for all basins with 2010 levels of land use except James River. Shoreline management was applied as specified in the Tributary Strategy, which was slightly more than a 20% reduction of shoreline loads used in Option 4. This scoping simulation corresponds to Scenario 1 from Table 1.1.

Scoping Scenario B (VAMWA Scenario 3)
This second scenario used the 2002 Model Assessment Scenario nutrient loads as described above in all the tidal regions of James River but the tidal fresh. The tidal fresh James region nutrient loads were set at Tier 2 (2010) levels for point and non-point sources. Tier 2 point source loads were set at 8.0 mg/L nitrogen and 1.0 mg/L phosphorus for municipal dischargers and industrial dischargers have nutrient levels reduced to half that of the Tier 1 levels or set at the permit limit, whichever is less. Throughout the James, the sediment loads were set at 2005 James Tributary Strategy levels. Tributary Strategies were used for all basins with 2010 levels of land use but James River. Shoreline management was applied as specified in the Tributary Strategy, which was slightly more than a 20% reduction of shoreline loads used in Option 4 scenario. This scenario corresponds to Scenario 3 from Table 1.1.

Scoping Scenario C (VAMWA Scenario 4)
Scoping Scenario C used Tier 1 nutrient loads in the James as described in the Tier 1 Scenario above, but substituted the 2005 James Tributary Strategy load of suspended sediment. Scoping Scenario C has the highest nutrient loads of all the scoping scenarios because Tier 1 point source loads were calculated as 2010 flows from point source dischargers combined with the 2000 point source concentrations (USEPA 2003b). Tributary Strategy loads were used for all basins, except for James with 2010 land use. Shoreline management was applied as specified in the Virginia Tributary Strategy scenario, which was slightly more than a 20% reduction of shoreline loads used in Option 4 scenario. This scenario corresponds to Scenario 3 from Table 1.1.

Scoping Scenario D
Scoping Scenario D used Tier 3 nutrient loads in the James as described in the Tier 3 Scenario above, but substituted the 2005 James Tributary Strategy load of suspended sediment. Tier 3 point source loads were at 5.0 mg/L and 0.5 mg/L for nitrogen and phosphorus respectively for municipal dischargers. Industrial dischargers reduce nutrient loads to 80% that of Tier 1 or the permit limit, whichever was less. Tributary Strategy loads were used for all basins with 2010 land use with the exception of James River. Shoreline management was applied as specified in the Virginia Tributary Strategy scenario, which was slightly more than a 20% reduction of shoreline loads used in Option 4 scenario.

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Cerco, CF and MR Noel. 2004. *The 2002 Chesapeake Bay Eutrophication Model*. EPA 903-R-04, U.S. EPA Chesapeake Bay Program Office, Annapolis, MD. July.

USEPA. 2003a. *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability*. EPA 903-R-03-004, U.S. EPA Chesapeake Bay Program Office, Annapolis, MD. October.

USEPA. 2003b. *Setting and Allocating the Chesapeake Bay Nutrient and Sediment Loads*. EPA 903-R-03-007, U.S. EPA Chesapeake Bay Program Office, Annapolis, MD. December.

Virginia. 2005. Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for the James River, Lynnhaven and Poquoson (March).

Table 2.1. James River basin model estimated total nitrogen (TN), total phosphorus (TP), and total suspended sediment (TSS) loads for point and non-point sources delivered to tidal waters. Nutrients in million pounds; sediments in million tons.

Scenario	TN	TP	TSS *
1985 Reference	46.9	8.51	1.28
2002 Assessment	37.7	5.80	1.18
Tier 1	37.3	6.20	1.14
Tier 2	28.2	5.04	1.07
Tier 3	23.0	3.91	0.95
VATS	25.4	3.49	0.82
VATS Alternate	23.9	3.37	0.82
Option 4	28.1	3.75	0.97
E3	15.2	2.83	0.79
Scoping Scenario A	37.6	6.31	0.82
Scoping Scenario B	33.8	5.77	0.82
Scoping Scenario C	36.1	6.13	0.82
Scoping Scenario D	22.6	3.90	0.82

* TSS loads were calculated from the watershed sediments but don't include: shoreline sediment reductions below the fall line.

Source: U.S. EPA Chesapeake Bay Program Office

Table 2.2. James River basin model estimated point source nitrogen and phosphorus loads and as a percent of total loads delivered to tidal waters. Nutrients in million pounds.

	Point Source			
	Nitrogen		Phosphorus	
Scenario	Million Pounds	Percent	Million Pounds	Percent
1985 Reference	23.3	50%	3.95	46%
2002 Assessment	15.1	40%	1.75	30%
Tier 1	16.7	45%	2.18	35%
Tier 2	10.3	37%	1.46	29%
Tier 3	6.9	30%	0.73	19%
VATS	11.2	44%	1.18	34%
VATS Alternate	9.7	41%	1.07	32%
Option 4	8.7	31%	0.72	19%
E3	4.5	30%	0.18	6%
Scoping Scenario A	15.6	42%	2.19	35%
Scoping Scenario B	12.8	38%	2.16	37%
Scoping Scenario C	16.7	46%	2.18	35%
Scoping Scenario D	6.9	30%	0.73	19%

Source: U.S. EPA Chesapeake Bay Program Office

Table 2.3. James River point source total nitrogen (TN) and total phosphorus (TP) loads (million pounds) delivered to the basin segment from the watershed model. (AFL- above fall line; lower estuary – everything below the tidal fresh)

	TN				TP			
SCENARIO	AFL	Tidal Fresh	Lower Estuary	TN Total	AFL	Tidal Fresh	Lower Estuary	TP Total
1985 Reference	1.13	15.0	7.2	23.3	0.55	1.57	1.83	3.95
2002 Assessment	0.86	7.9	6.4	15.1	0.72	0.50	0.53	1.75
Tier 1	2.05	6.8	7.9	16.7	0.77	0.80	0.61	2.18
Tier 2	0.74	5.7	3.9	10.3	0.34	0.64	0.48	1.46
Tier 3	0.80	3.7	2.4	6.9	0.16	0.33	0.24	0.73
VATS	0.84	5.0	5.4	11.2	0.38	0.34	0.46	1.18
VATS Alternative	0.79	5.0	3.9	9.7	0.38	0.34	0.35	1.07
Option 4	0.70	4.9	3.1	8.7	0.13	0.35	0.24	0.72
E3	0.62	2.6	1.3	4.5	0.04	0.10	0.04	0.18
Scoping A	1.15	6.7	7.7	15.6	0.99	0.57	0.63	2.19
Scoping B	0.76	5.7	6.4	12.8	0.99	0.64	0.53	2.16
Scoping C	2.05	6.8	7.9	16.7	0.77	0.80	0.61	2.18
Scoping D	0.80	3.7	2.4	6.9	0.16	0.33	0.24	0.73

Source: U.S. EPA Chesapeake Bay Program Office

Table 2.4. Management and scoping scenarios with a description of nutrient and sediment loadings. AFL - above fall line; TF – tidal fresh; LE – lower estuary; TS – tributary strategy; PS_{sig} – significant point sources; nutrients are given in million pounds, sediments in million tons.

Description	Regional nutrient removal assumptions			James sedim. removal assump.	Northern Bay nutrient removal	Year of land use flow animal pop'n	Other Information	
	AFL	TF	LE				PS_{sig}	NPS
1985 Reference	1985	1985	1985	1985	1985	1985	TN 46.9 mil lbs TP 8.51 mil lbs TSS 1.28 mil ttons	
2002 Assess (VAMWA Scn 2)	2002 Assess	2002 Assess	2002 Assess	2002 Assess	2002 Assess	2002	TN 37.7 TP 5.8 TSS 1.18	
Tier 1	Tier 1 Current	Tier Current	Tier 1 Current	Tier 1	Tier 1	2010	TN 37.3 TP 6.2 TSS 1.14 For existing NRT Sig PS TN 8mg/l Others TN 2000 All TP 2000 Ind = Current includes 2000 flows	Varies by BMP See TSD Appendix A for descriptions
Tier 2	Tier 2	Tier 2	Tier 2	Tier 2	Tier 2	2010	TN 28.2 TP 5.04 TSS 1.07 TN 8mg/l TP 1 mg/l Ind ½ Tier 1	"
Tier 3	Tier 3	Tier 3	Tier 3	Tier 3	Tier 3	2010	TN 23 TP 3.91 TSS .95 TN 5 mg/l TP .5 mg/l Ind 80% Tier 1	"
VATS (VAMWA Scn 5)	VATS	VATS	VATS	VATS	Tributary Strategies (TS)	2010	TN 25.4 TP 3.49 TSS ..82	
VATS Alternative	VATS (except PS loading reductions increased in MH and PH)			VATS	TS	2010	TN 23.9 TP 3.37 TSS .82 TN 5 mg/l TP .5 mg/l In James MH and PH	
Option 4	2000 Allocation	2000 Allocation	2000 Allocation	2000 Allocation	Tier 3 Potomac and North 2000 Allocation Rapp, York, ES	2010	TN 28.1 TP 3.75 TSS .97	
E3	E3	E3	E3	E3	E3	2010 Ind =2000 Flow	TN 15.2 TP 2.83 TSS .79 TN 3 mg/l TP .1 mg/l	
Scope A (VAMWA Scn 1)	1996	1996 BNR = 8 & 2	1996	VATS	TS	2002 James Land Use & Animal Pop 1996 Flow All Others 2010	TN 37.6 TP 6.31 TSS .82 Ind = ½ conc.	NPS Sediment at VATS TN TP at 2002
Scope B (VAMWA Scn 3)	2002 Progress	Tier 2	2002 Progress	VATS	TS	2002 James Land Use & Animal Pop 2010 Flow All	TN 33.8 TP 5.77 TSS .82 TN 8 TP 1 Ind = ½ Tier 1	
Scope C (VAMWA Scn 4)	Tier 1	Tier 1	Tier 1	VATS	TS	2010	TN 36.1 TP 6.13 TSS.82 2000 Conc.	
Scope D New	Tier 3	Tier 3	Tier 3	VATS	TS	2010	TN 22.61 TP 3.9 TSS.82 TN 5 mg/l TP .5 mg/l Ind 80% Tier 1	

Figure 2.1 The Tidal Fresh James region and associated watershed.

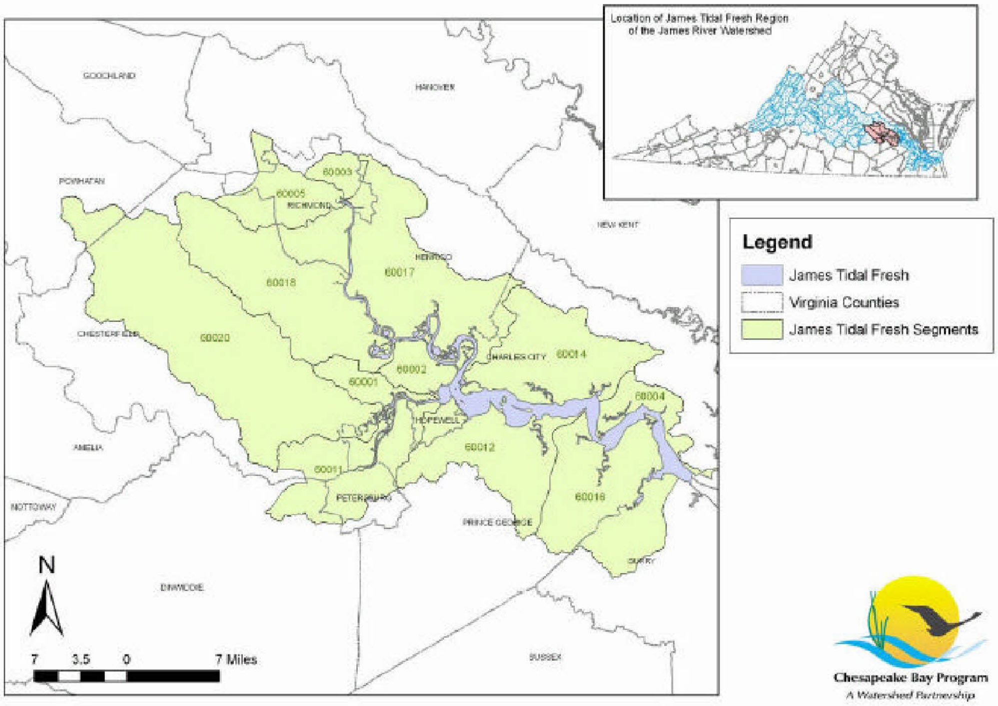
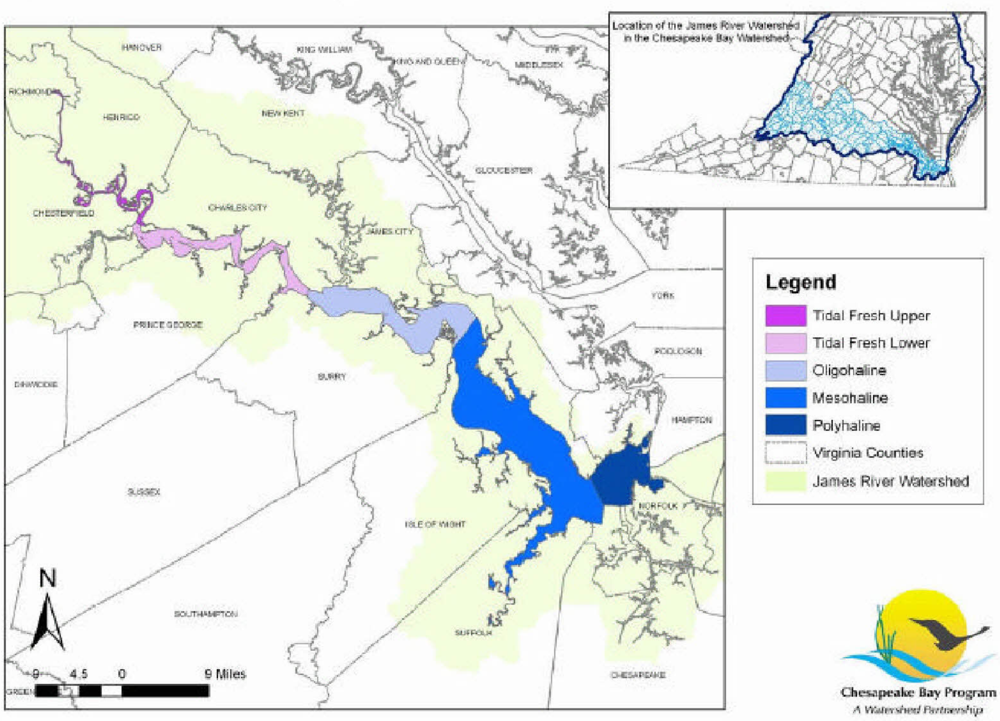


Figure 2.2. The five major segments of the tidal James River



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Chapter 3: SPRING AND SUMMER MEAN CHLOROPHYLL a FOR ALL BAY SEGMENTS AND JAMES CFD ANALYSIS

This chapter of the report summarizes the model estimated spring and summer chlorophyll *a* concentrations (μg/L) for all Bay segments and the cumulative frequency distribution (CFD) based attainment assessment of the proposed James River chlorophyll *a* criteria. This analysis was based on specific requests (Pomeroy 2005a,b). The chapter is organized in three sections preceded by key findings. Section 3.a contains model estimated ten-year average spring and summer chlorophyll *a* concentrations for thirteen scenarios for all major Chesapeake Bay segments. Table 3.1 contains estimates for key management scenarios while Table 3.2 reflects results calculated for the scoping scenarios. Section 3.b contains the CFD based attainment assessment of the proposed chlorophyll *a* criteria for the tidal James River segments for both a ten-year average and a running three-year average are presented in Tables 3.3 to 3.12 for nine management scenarios while Tables 3.13 to 3.22 present results for the four scoping scenarios. At the time of this analysis, there was no published reference CFD so a default reference curve was used that allowed for 10% non-attainment over space and time. It is believed this may have created more non-attainment than would be expected from a true reference curve.

The last section, 3.c, has box and whisker plots of observed and simulated chlorophyll *a* concentrations by tidal James River segment (Figures 3.1 through 3.14). Observed data from 1985 to 2004 by segment are presented in Figures 3.1 to 3.4. 'All Values' includes all single observations, 'Monthly Means' is the monthly average of all values and 'Annual Means' is the annual means of the twenty years of observations. Shown are the range, the 25^{th} and 75^{th} percentiles, and the median. Figures 3.5 through 3.14 represent model estimates of the seasonal chlorophyll *a* concentrations of the range, the 25^{th} and 75^{th} percentiles, and the median under the management and scoping scenarios. These estimates are based on monthly means across the ten year simulation.

Key Findings:

- The James Lower Tidal Fresh (JMSTF1) was the critical segment for nutrient reductions.
    - This region displayed the highest estimated summer chlorophyll *a* concentrations of all the segments and shows the greatest response to nutrient reductions with lower chlorophyll *a* concentrations based on 10 year averages and medians (Tables 3.1 and 3.2 and Figures 3.5 – 3.14).
    - 10-year mean was reduced by 11.5 μg/L from 2002 Assessment – VATS.
    - While useful comparisons for temporal and spatial responses, these seasonal averages should not be used to measure attainment.
- Except for JMSTF1, the mean concentrations do not vary more than 3.5 ug/L for the other segments (Table 3.1). Medians exhibit the same invariable pattern (Figures 3.5 – 3.14).
- Maximum values responded better than means or medians to nutrient reductions (Figures 3.5 – 3.14) indicating the frequency and magnitude of algal blooms is reduced.
- Table 3.1 indicates all criteria are met as 10 year averages under Tier 2 and Scoping Scenario B, but this same table does not reflect how attainment will be measured. Attainment is measured using 3-years of data and subjected to a cumulative frequency

analysis or CFD as shown in Tables 3.3. – 3.22. The CFD analysis results in non-attainment in segments that appear to be meeting the criteria in Tables 3.1 and 3.2.

- The CFD analysis was done without the aid of published reference curve for chlorophyll and observed data were compared to a default reference curve that allows non-attainment of 10% over space and time. A true reference curve based on the reference condition should result in better attainment in these segments.
- The ten-year CFD attainment results show more attainment than three-year CFD results.
- The CFD analysis (Tables 3.3. – 3.22) show attainment over many three year periods from 1986 through 1994 with all segments except TF1 and OH (summer) and MH and PH (spring).
- The CFD analysis of the scoping scenarios A – C (Tables 3.13 – 3.22) show a higher degree of non-attainment in TF2, TF1, OH (summer), MH (spring), PH (spring) than under VATS.
- Nutrient loads were the primary influence of chlorophyll *a* concentrations. Chlorophyll *a* criteria attainment improves significantly in scenarios where the sediment load reductions remain constant but nutrient levels decrease. This was seen when comparing scoping scenarios A - C to the Virginia Tributary Strategy scenario where the sediment loadings are set constant but nitrogen loadings decrease from 37.6 to 25.4. Non-attainment improved from 40% to below 1%.
- Sediment reductions alone did not improve chlorophyll *a* concentrations but could actually increase levels in certain regions. This included JMSTF2 and PAXTF as seen with Tiers 1, 2, 3, Opt 4 and VATS (Table 3.1)

Section 3.a: Ten-Year Average Spring and Summer Chlorophyll *a* Concentrations
The model estimated ten-year average spring and summer chlorophyll *a* concentrations for all major Chesapeake Bay segments (CB segments) are presented in Table 3.1. The spring chlorophyll season included the months of March through May. The summer chlorophyll season runs from July through September. The James Lower Tidal Fresh (JMSTF1) displayed the highest estimated summer chlorophyll *a* concentrations of all the CB segments in the 1985 Reference Scenario, and the second highest summer average concentration in the 2002 Assessment Scenario.

Table 3.2 contains the ten-year average spring and summer chlorophyll *a* concentrations for the scoping scenarios A-D. Scoping Scenario C was comparable to the Tier 1 Scenario as both had the same nutrient loads to the tidal James but Scoping Scenario C had the higher sediment reductions associated with Virginia Tributary Strategy. In comparing the ten-year average chlorophyll *a* concentrations between these scenarios only minor differences were seen. Scoping Scenario D and Tier 3 were an analogous case, with the main difference being the higher levels of the Virginia Tributary Strategy controls on sediment loads included in Scoping Scenario D. Again, differences in the ten-year chlorophyll *a* concentrations were trivial, indicating that nutrient loads are the primary influence of chlorophyll *a* concentrations. With the exception of the E3 scenario, which was considered to be currently economically infeasible, the best overall performance in proposed chlorophyll *a* criteria attainment was shown by scenarios with the largest nutrient controls such as the Virginia Tributary Strategy Alternative Scenario, followed by the Virginia Tributary Strategy Scenario (VATS). The better performance of the Virginia Tributary Strategy Alternative Scenario was particularly noted in the spring season in the mesohaline tidal James River. A summary of three year seasonal means for the same period is provided in Appendix B.

Section 3.b: James River CFD Analysis of Criteria Attainment

Tables 3.3 to 3.12 provide the cumulative frequency distribution (CFD) based chlorophyll *a* attainment assessment results. These results were stated as percent (%) non-attainment, for the five tidal James River segments of the Upper Tidal Fresh, Lower Tidal Fresh, Oligohaline, Mesohaline, and Polyhaline for both a ten-year average and a running three-year average. A green "A" represents attainment of the proposed water quality criteria, and red values indicate the percent of time and space the segment was not meeting the proposed chlorophyll *a* criteria. A blue value represents a value of one percent or less of the time and space a segment is in non-attainment.

Generally, attainment is assessed by plotting the data as a CFD and comparing that curve to a CFD developed from reference site data. The reference CFD estimates an accepted level of naturally occurring non-attainment. If the observed CFD is within the reference CFD, then the criterion is attained and all uses are met. However, for this analysis there is no published reference curve for chlorophyll and observed data are compared to a default reference curve that allows non-attainment of 10% over space and time. EPA has convened an academic committee to work on publication of a reference curve. EPA expects a reference curve based on the reference condition will result in more 'natural' non-attainment. This will result in better attainment in these segments.

Table 3.3 shows an unusual condition where almost all years achieve the chlorophyll *a* criteria except the last three-year period of 1992 to 1994. In this period the cause of non-attainment was due to one month, in one year, May 1994. In late April 1994 high flows were observed and simulated, along with high levels of nutrient loads delivered to the James Upper Tidal Fresh. A few weeks later, in May, blooms where observed in the James Upper Tidal Fresh. May's monthly average chlorophyll observed in the three James Upper Tidal Fresh tidal monitoring stations of TF5.2, TF5.2A, and TF5.3 were 19.5 µg/L, 47.3 µg/L, and 57.0 µg/L, respectively. This was an example of where hydrologic conditions cause high nutrient loads, in a once in a decade occurrence, which were estimated to exceed the criteria even under high and effective levels of nutrient control.

Tables 3.13 to 3.22 present the scoping scenario CFD based chlorophyll *a* attainment assessment results for each tidal James River segment. As described above, Tier 1 Scenario could be compared with Scoping Scenario C, and Tier 3 Scenario compared with Scoping Scenario D. With respect to the time and space considerations of criteria attainment as estimated by the CDF, criteria attainment based on chlorophyll between these management and scoping scenarios were trivial. This indicated nutrients were the primary driver of chlorophyll *a* concentrations. Nuances can be seen, for example in the James Upper Tidal Fresh summer where the Scoping Scenario C has a higher non-attainment (5.3%) compared to the Tier 1 Scenario (2.8%). This could be attributed to the greater reduction of suspended sediment in the water column under the Scoping Scenario C conditions reducing algae light limitations. The overall result was increased chlorophyll non-attainment. Alternately, in the James Lower Tidal Fresh – Summer, Scoping Scenario C has a slightly improved level of criteria attainment (50.4%), compared to Tier 1

(54.9%). This could be attributed to improved light conditions allowing simulated benthic algal biomass to increase which then competes with water column algae for nutrients. In each of these cases the differences are trivial, because the primary driver of tidal James River algal levels is nutrients.

The one apparent exception substantiates this. In the James Polyhaline –Spring, Scoping Scenario C has considerably less criteria non-attainment (28.8%) than Tier 1 (55.4%), but this was due to the differences in nutrient loads for this segment. In Scoping Scenario C all tributaries north of the James have the 2003 cap allocation levels of nutrients loads, but in the Tier 1 Scenario, Tier 1 levels of nutrient controls were applied throughout the Bay watershed. Because nutrient loads were the primary influence, chlorophyll *a* concentrations were reduced at higher levels of nutrient controls. However, in some cases nutrient controls also reduced sediment loads and improved light conditions for algae. The result was increased algal concentrations. This was best observed in the tidal fresh Patuxent River under the management simulations (Tier 1, 2, 3 and Option 4) under both spring and summer periods. A similar, but less dramatic response was simulated in the upper tidal fresh James River during the summer under several management simulations (Tier 2, Tier 3, Option 4 and VATS scenarios). However, as nutrient and sediment management increased, the model estimated that nutrient limitation began to have a greater effect on algal biomass than the improved clarity, and chlorophyll *a* concentrations decreased in the James Upper Tidal Fresh summer period.

Section 3.c: Observed and Simulated Chlorophyll *a* Concentrations by James River Segment

Box and whisker plots of James River chlorophyll *a* concentrations (µg/L) were developed from observed monitoring data from 1985 to 2004 by segment and presented in Figures 3.1 to 3.4. 'All Values' includes all single observations, 'Monthly Means' is the monthly average of all values and 'Annual Means' is the annual means of the twenty years of observations. Shown are the range, (max and min), the 25^{th} and 75^{th} percentiles, and the median. There was a general trend of reducing or dampening the variability of the observations toward annual means as it moves from all values to monthly means.

Box and whisker plots of model estimated James River chlorophyll *a* concentrations for spring and summer by tidal segment across all thirteen scenarios are presented in Figures 3.5 through 3.14. Once again the range, the 25^{th} and 75^{th} percentiles, and the median were developed from monthly means based on the 10 year simulations. With the exception of the upper tidal fresh James River (JMSTF2) for spring or summer, there appears to be a steady decrease in the magnitude of high chlorophyll *a* concentrations with increasing nutrient reductions under management scenarios throughout the River. As indicated above, the most significant decreases in the magnitude and frequency of high chlorophyll *a* concentrations occurred with higher nutrient reductions. Only scoping scenario D demonstrated similar results to VATS and VATS Alternative.

References:

Pomeroy, C.D. 2005a. Alternative Analysis for Chl STDs email dated February 09, 2005
Pomeroy, C.D. 2005b. Alternative Analysis for Chl STDs email dated April 15, 2005.

Table 3.1. Average spring and summer chlorophyll *a* concentrations(μg/L) by model scenario for major Chesapeake Bay segments.

Major CB Segment	1985 Reference Scenario		2002 Assess Scenario		Tier 1 Scenario		Tier 2 Scenario		Tier 3 Scenario		Option 4 Scenario		VATS Scenario		VATS Alt. Scenario		E3 Scenario	
	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
CB1TF	8.28	10.11	7.86	9.06	7.34	8.37	6.93	7.54	5.96	6.36	5.85	5.97	6.21	6.24	6.18	6.21	5.07	5.35
CB2OH	8.18	8.10	7.22	7.32	6.83	6.94	6.45	6.51	5.69	5.80	5.40	5.31	5.76	5.68	5.71	5.65	4.82	4.95
CB3MH	10.66	14.15	9.20	10.96	8.63	10.36	8.18	9.41	7.16	7.88	6.76	7.19	7.18	7.30	7.07	7.21	6.01	5.60
CB4MH	10.01	14.30	7.95	10.26	7.68	9.80	7.32	8.75	6.60	7.27	6.10	6.63	6.41	6.66	6.31	6.58	5.54	5.28
CB5MH	13.59	9.55	10.43	7.56	10.15	7.38	9.78	6.63	8.77	5.71	7.94	5.47	8.18	5.12	8.13	5.11	6.73	4.14
CB6PH	11.20	8.47	8.49	6.85	8.47	6.91	7.62	6.14	6.23	5.31	6.20	5.25	5.30	4.72	5.36	4.73	4.20	3.89
CB7PH	10.51	7.29	8.53	6.06	8.50	6.08	7.85	5.54	6.67	4.95	6.44	4.77	5.76	4.52	5.78	4.50	4.61	3.83
CB8PH	9.25	6.63	7.81	5.66	8.03	5.81	6.87	5.16	5.91	4.60	6.10	4.72	5.52	4.33	5.50	4.32	4.68	3.66
PAXTF	9.82	27.84	10.59	30.28	9.14	29.80	9.84	31.21	9.78	30.43	10.16	32.48	10.64	29.91	10.48	29.42	7.61	24.21
PAXOH	10.44	19.99	12.28	20.83	12.24	20.66	12.18	20.72	12.44	20.50	13.55	22.11	12.45	20.36	12.39	20.24	12.69	19.26
PAXMH	16.15	17.44	12.48	14.57	12.32	14.38	11.22	13.73	9.56	11.94	8.60	10.91	8.65	11.09	8.57	10.92	6.97	8.16
POTTF	5.97	23.53	5.30	17.47	5.14	16.68	5.13	14.83	4.88	12.50	4.56	8.57	4.92	8.47	4.78	11.90	3.89	10.49
POTOH	6.00	10.11	5.05	7.32	4.95	7.11	5.03	6.64	4.93	6.05	4.59	4.79	4.83	5.07	4.93	6.18	4.87	4.79
POTMH	16.44	12.33	14.40	10.04	13.40	9.71	13.23	8.74	10.42	7.30	10.07	6.89	9.22	6.48	9.28	6.53	6.83	4.93
RPPTF	6.07	26.33	6.77	19.76	6.32	18.26	6.45	15.21	6.96	12.14	7.01	10.84	7.23	10.62	7.22	11.22	6.29	8.26
RPPOH	6.82	12.10	7.31	10.64	7.32	10.56	7.44	9.77	7.59	8.95	7.51	8.40	7.75	8.03	7.80	8.29	7.30	6.99
RPPMH	13.48	9.67	9.79	7.90	9.81	7.96	8.60	7.29	7.28	6.51	6.95	6.25	6.24	5.77	6.37	5.86	5.04	4.78
MPNTF	2.78	5.89	2.51	4.61	2.49	4.62	2.40	4.38	2.30	4.26	2.19	3.54	2.27	4.00	2.35	4.34	2.20	4.11
MPNOH	3.65	11.45	3.67	9.99	3.68	10.17	3.79	9.47	3.97	8.47	3.78	8.22	3.95	7.85	3.96	8.26	3.92	6.77
PMKTF	2.77	7.29	2.81	7.81	3.31	7.89	3.22	7.82	3.06	7.36	3.14	7.67	2.93	7.48	2.96	7.47	2.83	6.28
PMKOH	4.91	11.21	4.90	11.08	5.08	11.27	4.95	11.08	4.66	10.38	4.83	10.30	4.67	10.13	4.68	10.38	4.13	8.59
YRKMH	15.13	12.06	11.61	10.92	11.91	11.14	10.99	10.82	9.76	9.98	9.58	9.63	9.12	9.35	9.44	9.73	7.71	8.16
YRKPH	11.82	7.99	8.47	6.85	8.53	6.87	7.48	6.51	6.39	6.03	6.21	5.89	5.66	5.57	5.88	5.69	4.84	4.98
PIAMH	12.10	10.51	7.53	7.11	7.64	7.57	6.70	6.25	5.44	5.26	5.36	5.26	4.82	4.72	4.89	4.72	3.57	3.55
MOBPH	8.90	9.08	6.71	7.44	6.78	7.35	5.99	6.73	5.11	5.94	4.83	5.73	4.41	5.32	4.57	5.48	3.75	4.45
JMSTF2	**6.82**	**8.86**	**5.93**	**9.03**	**6.26**	**9.44**	**5.99**	**9.48**	**5.00**	**9.14**	**5.80**	**10.00**	**5.32**	**9.51**	**5.64**	**9.87**	**3.71**	**8.65**
JMSTF1	**16.37**	**34.66**	**11.89**	**24.49**	**11.76**	**25.91**	**10.31**	**19.11**	**9.04**	**14.74**	**10.02**	**16.74**	**8.50**	**12.97**	**9.15**	**15.20**	**6.65**	**10.56**
JMSOH	**13.74**	**13.85**	**10.39**	**12.68**	**9.81**	**12.67**	**8.52**	**11.65**	**7.50**	**10.42**	**8.17**	**11.10**	**6.88**	**9.32**	**7.35**	**10.23**	**6.06**	**8.06**
JMSMH	**13.00**	**5.59**	**10.14**	**5.32**	**10.07**	**5.33**	**8.46**	**5.17**	**7.28**	**4.94**	**7.87**	**4.92**	**7.00**	**4.62**	**7.13**	**4.85**	**5.88**	**4.33**
JMSPH	**14.26**	**6.62**	**10.79**	**5.90**	**11.33**	**6.01**	**9.00**	**5.50**	**7.54**	**4.99**	**8.13**	**5.12**	**7.34**	**4.73**	**7.24**	**4.76**	**5.83**	**4.01**
CHOOH	10.55	21.94	10.29	20.41	10.28	20.51	10.01	19.52	9.63	18.32	9.75	18.29	9.06	17.74	9.00	17.57	8.11	14.25
CHOMH2	9.36	13.18	7.42	9.97	7.63	10.02	7.11	8.79	6.25	7.32	5.80	6.84	5.87	6.61	5.81	6.44	4.34	4.52
CHOMH1	7.91	9.84	6.38	7.45	6.38	7.40	6.01	6.58	5.24	5.70	4.83	5.28	4.77	5.23	4.72	5.16	4.01	4.04
EASMH	8.05	15.30	5.86	10.03	5.69	9.67	5.34	8.47	4.79	6.83	4.24	5.80	4.57	6.29	4.54	6.25	3.97	4.92
TANMH	12.46	9.37	10.16	7.82	10.07	7.78	9.23	7.31	8.14	6.71	7.14	5.96	7.41	6.34	7.40	6.33	6.17	5.43
POCMH	11.49	12.49	8.54	9.06	9.07	9.56	7.59	8.56	6.24	7.63	4.82	5.06	5.64	6.98	5.64	6.94	4.66	5.18

Table 3.2. Average spring and summer chlorophyll *a* concentrations (μg/L) for major Chesapeake Bay segment for the scoping scenarios based on monthly means over the ten year simulation.

Major CB Segment	**Scoping Scenario A**		**Scoping Scenario B**		**Scoping Scenario C**		**Scoping Scenario D**	
	Spring	***Summer***	***Spring***	***Summer***	***Spring***	***Summer***	***Spring***	***Summer***
CB1TF	6.21	6.24	6.21	6.24	6.21	6.24	6.21	6.24
CB2OH	5.76	5.70	5.76	5.70	5.76	5.70	5.76	5.69
CB3MH	7.20	7.34	7.20	7.34	7.20	7.34	7.19	7.30
CB4MH	6.45	6.70	6.44	6.69	6.45	6.70	6.42	6.66
CB5MH	8.26	5.17	8.25	5.16	8.27	5.17	8.20	5.12
CB6PH	5.35	4.80	5.34	4.79	5.35	4.80	5.29	4.72
CB7PH	5.81	4.58	5.79	4.57	5.80	4.58	5.74	4.51
CB8PH	6.19	4.76	5.88	4.62	6.09	4.76	5.40	4.23
PAXTF	10.64	29.91	10.64	29.91	10.64	29.91	10.64	29.91
PAXOH	12.45	20.36	12.45	20.36	12.45	20.36	12.45	20.36
PAXMH	8.67	11.13	8.66	11.12	8.67	11.13	8.64	11.09
POTTF	4.92	8.49	4.92	8.49	4.92	8.49	4.92	8.49
POTOH	4.86	5.10	4.86	5.10	4.86	5.10	4.86	5.10
POTMH	9.26	6.52	9.25	6.51	9.26	6.52	9.23	6.48
RPPTF	7.23	10.67	7.23	10.67	7.23	10.67	7.23	10.67
RPPOH	7.76	8.08	7.76	8.08	7.76	8.08	7.76	8.07
RPPMH	6.28	5.82	6.27	5.81	6.27	5.82	6.24	5.77
MPNTF	2.27	4.01	2.27	4.01	2.27	4.01	2.27	4.01
MPNOH	3.95	7.92	3.95	7.92	3.95	7.92	3.95	7.91
PMKTF	2.93	7.50	2.93	7.50	2.93	7.50	2.93	7.50
PMKOH	4.68	10.18	4.68	10.18	4.68	10.18	4.68	10.18
YRKMH	9.16	9.42	9.15	9.41	9.16	9.42	9.12	9.38
YRKPH	5.72	5.63	5.71	5.61	5.72	5.63	5.67	5.57
PIAMH	4.84	4.80	4.83	4.78	4.84	4.79	4.80	4.75
MOBPH	4.45	5.42	4.45	5.40	4.45	5.42	4.41	5.33
JMSTF2	**5.19**	**9.49**	**6.10**	**9.49**	**6.26**	**9.82**	**4.80**	**9.15**
JMSTF1	**10.19**	**20.19**	**10.15**	**17.67**	**10.45**	**20.32**	**8.38**	**12.08**
JMSOH	**8.57**	**11.57**	**8.40**	**11.17**	**8.41**	**11.55**	**6.88**	**9.35**
JMSMH	**8.77**	**4.95**	**8.29**	**4.90**	**8.64**	**4.95**	**6.68**	**4.57**
JMSPH	**9.62**	**5.34**	**8.56**	**5.17**	**9.33**	**5.33**	**6.87**	**4.60**
CHOOH	9.06	17.75	9.06	17.75	9.06	17.75	9.06	17.74
CHOMH2	5.88	6.63	5.88	6.63	5.88	6.63	5.87	6.61
CHOMH1	4.79	5.26	4.79	5.25	4.80	5.26	4.78	5.23
EASMH	4.59	6.36	4.59	6.34	4.60	6.36	4.58	6.29
TANMH	7.46	6.38	7.45	6.37	7.46	6.38	7.41	6.34
POCMH	5.66	7.02	5.66	7.01	5.66	7.02	5.63	6.97

Table 3.3. The CFD based assessment of spring chlorophyll water quality criteria attainment in the James Upper Tidal Fresh (JMSTF2). A = attainment; % = percent of time/space not in attainment.

James Upper Tidal Fresh - Spring				SCENARIOS					
Years of 3-Yr Running Avg	*'85 Ref.*	*'02 Progr.*	*Tier 1*	*Tier 2*	*Tier 3*	*Opt. 4*	*VATS*	*VATS Altern.*	*E3*
1985-1987	--	--	--	--	--	--	--	--	--
1986-1988	A	A	A	A	A	A	A	A	A
1987-1989	A	A	A	A	A	A	A	A	A
1988-1990	A	A	A	A	A	A	A	A	A
1989-1991	A	A	A	A	A	A	A	A	A
1990-1992	A	A	A	A	A	A	A	A	A
1991-1993	A	A	A	A	A	A	A	A	A
1992-1994	19.3%	19.3%	19.3%	19.6%	19.6%	20.1%	19.6%	19.6%	2.0%
Avg of 3-Yr Pds	2.8%	2.8%	2.8%	2.8%	2.8%	2.9%	2.8%	2.8%	0.3%
10-Year Avg	3.9%	3.9%	3.9%	4.0%	4.0%	4.3%	4.0%	4.0%	A

Table 3.4. The CFD based assessment of proposed summer chlorophyll water quality criteria attainment in the James Upper Tidal Fresh (JMSTF2). A = attainment; % = percent of time/space not in attainment.

James Upper Tidal Fresh - Summer				SCENARIOS					
Years of 3-Yr Running Avg	*'85 Ref.*	*'02 Progr.*	*Tier 1*	*Tier 2*	*Tier 3*	*Opt. 4*	*VATS*	*VATS Altern.*	*E3*
1985-1987	1.7%	16.3%	18.5%	18.4%	16.0%	19.2%	17.5%	17.5%	1.7%
1986-1988	1.7%	22.9%	22.9%	27.7%	25.8%	34.5%	24.3%	24.3%	4.3%
1987-1989	A	11.8%	10.3%	17.6%	17.3%	22.6%	17.9%	17.9%	4.3%
1988-1990	A	2.0%	0.1%	4.6%	4.7%	10.0%	2.1%	2.1%	A
1989-1991	A	A	A	A	A	A	A	A	A
1990-1992	A	A	A	A	A	A	A	A	0.4%
1991-1993	0.6%	A	A	A	A	A	A	A	0.4%
1992-1994	0.6%	A	A	A	A	A	A	A	0.9%
Avg of 3-Yr Pds	0.6%	6.6%	6.5%	8.5%	8.0%	10.8%	7.7%	7.7%	1.5%
10-Year Avg	0.0%	3.1%	2.8%	4.6%	3.9%	6.5%	3.3%	3.3%	0.0%

Table 3.5. The CFD based assessment of spring chlorophyll water quality criteria attainment in the James Lower Tidal Fresh (JMSTF1) A = attainment; % = percent of time/space not in attainment.

James Lower Tidal Fresh - Spring				*SCENARIOS*					
Years of 3-Yr Running Avg	*'85 Ref.*	*'02 Progr.*	*Tier 1*	*Tier 2*	*Tier 3*	*Opt. 4*	*VATS*	*VATS Altern.*	*E3*
1985-1987	--	--	--	--	--	--	--	--	--
1986-1988	38.2%	27.9%	29.0%	10.5%	7.4%	8.9%	A	A	A
1987-1989	41.5%	31.1%	31.3%	10.5%	7.4%	8.9%	A	A	A
1988-1990	53.3%	33.9%	33.9%	10.5%	7.4%	8.9%	A	A	A
1989-1991	41.8%	7.9%	6.8%	A	A	A	A	A	A
1990-1992	35.9%	6.4%	4.6%	A	A	A	A	A	A
1991-1993	24.0%	3.5%	2.1%	A	A	A	A	A	A
1992-1994	17.3%	3.5%	2.1%	A	A	A	A	A	A
Avg of 3-Yr Pds	36.0%	16.3%	15.7%	4.5%	3.2%	3.8%	0.0%	0.0%	0.0%
10-Year Avg	34.6%	12.9%	12.2%	1.2%	0.3%	0.7%	A	A	A

Table 3.6. The CFD based assessment of proposed summer chlorophyll water quality criteria attainment in the James Lower Tidal Fresh (JMSTF1). A = attainment; % = percent of time/space not in attainment.

James Lower Tidal Fresh - Summer				*SCENARIOS*					
Years of 3-Yr Running Avg	*'85 Ref.*	*'02 Progr.*	*Tier 1*	*Tier 2*	*Tier 3*	*Opt. 4*	*VATS*	*VATS Altern.*	*E3*
1985-1987	49.2%	25.0%	27.5%	10.8%	A	A	A	A	A
1986-1988	66.7%	40.8%	42.8%	28.6%	1.7%	12.9%	A	A	A
1987-1989	77.5%	60.6%	61.8%	52.6%	23.0%	43.0%	4.3%	4.7%	A
1988-1990	77.5%	69.1%	69.8%	66.6%	26.3%	53.9%	4.3%	4.7%	A
1989-1991	74.3%	59.7%	60.5%	52.8%	24.5%	48.9%	4.0%	4.5%	A
1990-1992	74.3%	50.2%	51.8%	41.7%	7.5%	28.9%	A	A	A
1991-1993	74.3%	59.1%	59.8%	33.5%	4.2%	20.3%	A	A	A
1992-1994	76.3%	46.8%	50.9%	20.4%	A	5.6%	A	A	A
Avg of 3-Yr Pds	71.3%	51.4%	53.1%	38.4%	10.9%	26.7%	1.6%	1.7%	0.0%
10-Year Avg	76.5%	52.4%	54.9%	36.1%	5.8%	20.7%	0.2%	0.2%	A

Table 3.7. The CFD based assessment of spring chlorophyll water quality criteria attainment in the James Oligohaline (JMSOH). A = attainment; % = percent of time/space not in attainment.

James Oligohaline - Spring				SCENARIOS					
Years of 3-Yr Running Avg	*'85 Ref.*	*'02 Progr.*	*Tier1*	*Tier2*	*Tier3*	*Opt. 4*	*VATS*	*VATS Altern.*	*E3*
1985-1987	--	--	--	--	--	--	--	--	--
1986-1988	20.1%	A	A	A	A	A	A	A	A
1987-1989	44.2%	A	A	A	A	A	A	A	A
1988-1990	71.2%	18.3%	16.4%	A	A	A	A	A	A
1989-1991	55.5%	18.3%	16.4%	A	A	A	A	A	A
1990-1992	51.0%	18.3%	16.4%	A	A	A	A	A	A
1991-1993	24.7%	A	A	A	A	A	A	A	A
1992-1994	10.5%	A	A	A	A	A	A	A	A
Avg of 3-Yr Pds	39.6%	7.9%	7.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
10-Year Avg	31.9%	3.6%	3.0%	A	A	A	A	A	A

Table 3.8. The CFD based assessment of proposed summer chlorophyll water quality criteria attainment in the James Oligohaline (JMSOH). A = attainment; % = percent of time/space not in attainment.

James Oligohaline - Summer				SCENARIOS					
Years of 3-Yr Running Avg	*'85 Ref.*	*'02 Progr.*	*Tier1*	*Tier2*	*Tier3*	*Opt. 4*	*VATS*	*VATS Altern.*	*E3*
1985-1987	A	A	A	A	A	A	A	A	A
1986-1988	4.3%	0.7%	0.5%	A	A	A	A	A	A
1987-1989	26.4%	23.8%	23.2%	20.3%	18.2%	20.8%	20.1%	20.1%	15.1%
1988-1990	28.7%	23.8%	23.4%	20.3%	18.2%	20.8%	20.1%	20.1%	15.1%
1989-1991	38.6%	34.7%	34.6%	17.7%	17.8%	20.1%	20.1%	20.1%	15.1%
1990-1992	36.0%	30.0%	30.0%	11.1%	5.5%	9.3%	A	A	A
1991-1993	44.5%	35.6%	35.4%	11.9%	5.5%	9.3%	A	A	A
1992-1994	33.3%	19.6%	19.3%	11.9%	5.5%	9.3%	A	A	A
Avg of 3-Yr Pds	26.5%	21.0%	20.8%	11.7%	8.8%	11.2%	7.5%	7.5%	5.7%
10-Year Avg	23.3%	16.0%	15.8%	8.0%	5.5%	7.7%	4.1%	4.0%	2.1%

Table 3.9. The CFD based assessment of spring chlorophyll water quality criteria attainment in the James Mesohaline (JMSMH). A = attainment; % = percent of time/space not in attainment.

James Mesohaline - Spring				*SCENARIOS*					
Years of 3-Yr Running Avg	*'85 Ref.*	*'02 Progr.*	*Tier1*	*Tier2*	*Tier3*	*Opt. 4*	*VATS*	*VATS Altern.*	*E3*
1985-1987	--	--	--	--	--	--	--	--	--
1986-1988	35.7%	33.8%	34.0%	25.7%	11.4%	20.1%	7.1%	1.8%	A
1987-1989	38.1%	35.1%	35.2%	26.2%	11.4%	20.1%	7.1%	1.8%	A
1988-1990	55.1%	53.8%	53.9%	45.9%	23.9%	30.6%	18.3%	8.1%	A
1989-1991	55.1%	53.9%	53.9%	50.5%	33.5%	37.3%	30.8%	12.9%	A
1990-1992	74.2%	63.8%	64.7%	59.1%	37.8%	45.4%	31.6%	12.9%	A
1991-1993	48.3%	34.3%	35.5%	31.5%	22.9%	29.8%	17.9%	6.4%	A
1992-1994	16.9%	6.4%	7.3%	4.3%	0.1%	3.4%	A	A	A
Avg of 3-Yr Pds	46.2%	40.2%	40.7%	34.8%	20.1%	26.7%	16.1%	6.3%	0.0%
10-Year Avg	38.9%	33.2%	33.6%	27.9%	14.6%	20.9%	10.4%	2.5%	A

Table 3.10. The CFD based assessment of proposed summer chlorophyll water quality criteria attainment in the James Mesohaline (JMSMH). A = attainment; % = percent of time/space not in attainment.

James Mesohaline - Summer				*SCENARIOS*					
Years of 3-Yr Running Avg	*'85 Ref.*	*'02 Progr.*	*Tier1*	*Tier2*	*Tier3*	*Opt. 4*	*VATS*	*VATS Altern.*	*E3*
1985-1987	A	A	A	A	A	A	A	A	A
1986-1988	A	A	A	A	A	A	A	A	A
1987-1989	A	A	A	A	A	A	A	A	A
1988-1990	A	A	A	A	A	A	A	A	A
1989-1991	A	A	A	A	A	A	A	A	A
1990-1992	A	A	A	A	A	A	A	A	A
1991-1993	10.0%	7.0%	6.9%	5.7%	3.7%	4.4%	1.8%	0.6%	A
1992-1994	9.3%	7.0%	6.8%	5.7%	3.7%	4.4%	1.8%	0.6%	A
Avg of 3-Yr Pds	2.4%	1.7%	1.7%	1.4%	0.9%	1.1%	0.4%	0.2%	0.0%
10-Year Avg	0.2%	0.1%	0.1%	A	A	A	A	A	A

Table 3.11. The CFD based assessment of spring chlorophyll water quality criteria attainment in the James Polyhaline (JMSPH). A = attainment; % = percent of time/space not in attainment.

James Polyhaline - Spring *Years of 3-Yr Running Avg*	*SCENARIOS* *'85 Ref.*	*'02 Progr.*	*Tier1*	*Tier2*	*Tier3*	*Opt. 4*	*VATS*	*VATS Altern.*	*E3*
1985-1987	77.5%	68.4%	77.5%	32.9%	20.1%	20.1%	20.1%	20.1%	A
1986-1988	77.5%	65.4%	77.5%	32.9%	20.1%	20.1%	20.1%	20.1%	A
1987-1989	52.6%	49.6%	52.6%	20.1%	20.1%	20.1%	20.1%	20.1%	A
1988-1990	52.6%	36.2%	40.0%	A	A	A	A	A	A
1989-1991	52.6%	29.8%	33.5%	8.0%	3.5%	6.1%	A	A	A
1990-1992	77.5%	33.1%	42.6%	8.0%	3.5%	6.1%	A	A	A
1991-1993	77.5%	36.8%	50.0%	23.3%	6.7%	17.9%	A	A	A
1992-1994	59.7%	16.3%	28.4%	7.3%	A	4.6%	A	A	A
Avg of 3-Yr Pds	66.0%	41.9%	50.3%	16.6%	9.3%	11.9%	7.5%	7.5%	0.0%
10-Year Avg	72.1%	45.4%	55.4%	14.4%	5.7%	9.1%	4.0%	3.5%	A

Table 3.12. The CFD based assessment of proposed summer chlorophyll water quality criteria attainment in the James Polyhaline (JMSPH). A = attainment; % = percent of time/space not in attainment.

James Polyhaline - Summer *Years of 3-Yr Running Avg*	*SCENARIOS* *'85 Ref.*	*'02 Progr.*	*Tier1*	*Tier2*	*Tier3*	*Opt. 4*	*VATS*	*VATS Altern.*	*E3*
1985-1987	0.4%	A	A	A	A	A	A	A	A
1986-1988	0.4%	A	A	A	A	A	A	A	A
1987-1989	11.1%	3.5%	3.9%	1.7%	A	0.4%	A	A	A
1988-1990	8.0%	3.5%	3.9%	1.7%	A	0.4%	A	A	A
1989-1991	8.0%	3.5%	3.9%	1.7%	A	0.4%	A	A	A
1990-1992	A	A	A	A	A	A	A	A	A
1991-1993	A	A	A	A	A	A	A	A	A
1992-1994	A	A	A	A	A	A	A	A	A
Avg of 3-Yr Pds	3.5%	1.3%	1.5%	0.6%	0.0%	0.1%	0.0%	0.0%	0.0%
10-Year Avg	0.0%	A	A	A	A	A	A	A	A

Table 3.13. The CFD based assessment of spring chlorophyll water quality criteria attainment in the James Upper Tidal Fresh (JMSTF2) for the scoping scenarios. A = attainment; % = percent of time/space not in attainment.

James Upper Tidal Fresh - Spring Years of 3-Yr Running Average	A	SCENARIOS Scoping Scenario B	C	D	VATS	VATS Alternative
1985-1987	--	--	--	--	--	--
1986-1988	A	A	A	A	A	A
1987-1989	A	A	A	A	A	A
1988-1990	A	A	A	A	A	A
1989-1991	A	A	A	A	A	A
1990-1992	A	A	A	A	A	A
1991-1993	A	A	A	A	A	A
1992-1994	19.3%	19.6%	19.6%	19.6%	19.6%	19.6%
Average of 3-Yr Periods	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%
10-year Average	3.9%	4.0%	4.0%	4.0%	4.0%	4.0%

Table 3.14. The CFD based assessment of proposed summer chlorophyll water quality criteria attainment in the James Upper Tidal Fresh (JMSTF2) for the scoping scenarios. A = attainment; % = percent of time/space not in attainment.

James Upper Tidal Fresh - Summer Years of 3-Yr Running Average	A	SCENARIOS Scoping Scenario B	C	D	VATS	VATS Alternative
1985-1987	16.0%	19.6%	23.1%	13.4%	17.5%	17.5%
1986-1988	20.8%	25.9%	29.5%	18.8%	24.3%	24.3%
1987-1989	10.8%	16.2%	17.3%	13.6%	17.9%	17.9%
1988-1990	0.3%	1.6%	1.7%	0.8%	2.1%	2.1%
1989-1991	A	A	A	A	A	A
1990-1992	A	A	A	A	A	A
1991-1993	A	A	A	A	A	A
1992-1994	A	A	A	A	A	A
Average of 3-Yr Periods	6.0%	7.9%	9.0%	5.8%	7.7%	7.7%
10-year Average	2.1%	3.7%	4.8%	1.5%	3.3%	3.3%

Table 3.15. The CFD based assessment of proposed spring chlorophyll water quality criteria attainment in the James Lower Tidal Fresh (JMSTF1) for the scoping scenarios. A = attainment; % = percent of time/space not in attainment.

James Lower Tidal Fresh - Spring	SCENARIOS					
Years of 3-Yr		Scoping Scenario				VATS
Running Average	A	B	C	D	VATS	Alternative
1985-1987	--	--	--	--	--	--
1986-1988	10.1%	9.8%	10.6%	A	A	A
1987-1989	17.8%	9.8%	13.9%	A	A	A
1988-1990	17.8%	9.8%	13.9%	A	A	A
1989-1991	1.7%	A	A	A	A	A
1990-1992	A	A	A	A	A	A
1991-1993	A	A	A	A	A	A
1992-1994	A	A	A	A	A	A
Average of 3-Yr Periods	6.8%	4.2%	5.5%	0.0%	0.0%	0.0%
10-year Average	2.3%	1.0%	1.5%	A	A	A

Table 3.16. The CFD based assessment of proposed summer chlorophyll water quality criteria attainment in the James Lower Tidal Fresh (JMSTF1) for the scoping scenarios. A = attainment; % = percent of time/space not in attainment.

James Lower Tidal Fresh - Summer	SCENARIOS					
Years of 3-Yr		Scoping Scenario				VATS
Running Average	A	B	C	D	VATS	Alternative
1985-1987	15.7%	A	10.7%	A	A	A
1986-1988	33.7%	14.1%	28.8%	A	A	A
1987-1989	57.7%	44.6%	52.6%	A	4.3%	4.7%
1988-1990	67.0%	57.9%	67.0%	A	4.3%	4.7%
1989-1991	54.0%	51.4%	54.1%	A	4.0%	4.5%
1990-1992	43.2%	38.5%	43.3%	A	A	A
1991-1993	37.2%	29.7%	38.2%	A	A	A
1992-1994	24.8%	17.4%	26.1%	A	A	A
Average of 3-Yr Periods	41.7%	31.7%	40.1%	0.0%	1.6%	1.7%
10-year Average	39.5%	26.6%	38.3%	A	0.2%	0.2%

Table 3.17. The CFD based assessment of spring chlorophyll water quality criteria attainment in the James Oligohaline (JMSOH) for the scoping scenarios. A = attainment; % = percent of time/space not in attainment.

James Oligohaline - Spring Years of 3-Yr Running Average	A	SCENARIOS Scoping Scenario B	C	D	VATS	VATS Alternative
1985-1987	--	--	--	--	--	--
1986-1988	A	A	A	A	A	A
1987-1989	A	A	A	A	A	A
1988-1990	13.0%	12.3%	0.4%	A	A	A
1989-1991	13.0%	12.3%	0.4%	A	A	A
1990-1992	13.0%	12.3%	0.4%	A	A	A
1991-1993	A	A	A	A	A	A
1992-1994	A	A	A	A	A	A
Average of 3-Yr Periods	5.6%	5.3%	0.2%	0.0%	0.0%	0.0%
10-year Average	1.9%	1.7%	A	A	A	A

Table 3.18. The CFD based assessment of proposed summer chlorophyll water quality criteria attainment in the James Oligohaline (JMSOH) for the scoping scenarios. A = attainment; % = percent of time/space not in attainment.

James Oligohaline - Summer Years of 3-Yr Running Average	A	SCENARIOS Scoping Scenario B	C	D	VATS	VATS Alternative
1985-1987	A	A	A	A	A	A
1986-1988	A	A	A	A	A	A
1987-1989	21.5%	20.9%	21.8%	20.1%	20.1%	20.1%
1988-1990	21.5%	20.9%	21.8%	20.1%	20.1%	20.1%
1989-1991	20.4%	20.1%	20.5%	20.1%	20.1%	20.1%
1990-1992	12.1%	9.5%	12.1%	0.2%	A	A
1991-1993	12.5%	9.5%	12.7%	0.2%	A	A
1992-1994	12.3%	9.5%	12.3%	0.2%	A	A
Average of 3-Yr Periods	12.5%	11.3%	12.7%	7.6%	7.5%	7.5%
10-year Average	8.8%	7.8%	8.8%	4.2%	4.1%	4.0%

Table 3.19. The CFD based assessment of spring chlorophyll water quality criteria attainment in the James Mesohaline (JMSMH) for the scoping scenarios. A = attainment; % = percent of time/space not in attainment.

James Mesohaline - Spring	SCENARIOS					
Years of 3-Yr	Scoping Scenario					VATS
Running Average	A	B	C	D	VATS	Alternative
1985-1987	--	--	--	--	--	--
1986-1988	31.0%	25.8%	29.6%	4.1%	7.1%	1.8%
1987-1989	31.3%	26.0%	29.8%	4.1%	7.1%	1.8%
1988-1990	50.1%	45.2%	48.7%	16.4%	18.3%	8.1%
1989-1991	52.9%	52.8%	52.8%	21.6%	30.8%	12.9%
1990-1992	62.2%	61.6%	61.9%	22.3%	31.6%	12.9%
1991-1993	32.2%	31.4%	31.7%	8.5%	17.9%	6.4%
1992-1994	4.9%	4.2%	4.5%	A	A	A
Average of 3-Yr Periods	37.8%	35.3%	37.0%	11.0%	16.1%	6.3%
10-year Average	31.0%	28.5%	30.2%	6.3%	10.4%	2.5%

Table 3.20. The CFD based assessment of proposed summer chlorophyll water quality criteria attainment in the James Mesohaline (JMSMH) for the scoping scenarios. A = attainment; % = percent of time/space not in attainment.

James Mesohaline - Summer	SCENARIOS					
Years of 3-Yr	Scoping Scenario					VATS
Running Average	A	B	C	D	VATS	Alternative
1985-1987	A	A	A	A	A	A
1986-1988	A	A	A	A	A	A
1987-1989	A	A	A	A	A	A
1988-1990	A	A	A	A	A	A
1989-1991	A	A	A	A	A	A
1990-1992	A	A	A	A	A	A
1991-1993	4.9%	4.6%	4.8%	0.9%	1.8%	0.6%
1992-1994	4.9%	4.6%	4.8%	0.9%	1.8%	0.6%
Average of 3-Yr Periods	1.2%	1.2%	1.2%	0.2%	0.4%	0.2%
10-year Average	A	A	A	A	A	A

Table 3.21. The CFD based assessment of spring chlorophyll water quality criteria attainment in the James Polyhaline (JMSPH) for the scoping scenarios. A = attainment; % = percent of time/space not in attainment.

James Polyhaline - Spring Years of 3-Yr Running Average	A	SCENARIOS Scoping Scenario B	C	D	VATS	VATS Alternative
1985-1987	63.9%	22.8%	63.1%	20.1%	20.1%	20.1%
1986-1988	45.7%	22.8%	38.3%	20.1%	20.1%	20.1%
1987-1989	34.4%	20.1%	25.8%	20.1%	20.1%	20.1%
1988-1990	19.3%	0.1%	8.4%	A	A	A
1989-1991	20.8%	11.7%	16.5%	A	A	A
1990-1992	20.8%	11.7%	16.5%	A	A	A
1991-1993	24.7%	19.8%	23.7%	A	A	A
1992-1994	8.4%	5.8%	8.4%	A	A	A
Average of 3-Yr Periods	29.7%	14.4%	25.1%	7.5%	7.5%	7.5%
10-year Average	33.0%	11.6%	28.8%	3.5%	4.0%	3.5%

Table 3.22. The CFD based assessment of proposed summer chlorophyll water quality criteria attainment in the James Polyhaline (JMSPH) for the scoping scenarios. A = attainment; % = percent of time/space not in attainment.

James Polyhaline - Summer Years of 3-Yr Running Average	A	SCENARIOS Scoping Scenario B	C	D	VATS	VATS Alternative
1985-1987	A	A	A	A	A	A
1986-1988	A	A	A	A	A	A
1987-1989	0.4%	0.4%	0.4%	A	A	A
1988-1990	0.4%	0.4%	0.4%	A	A	A
1989-1991	0.4%	0.4%	0.4%	A	A	A
1990-1992	A	A	A	A	A	A
1991-1993	A	A	A	A	A	A
1992-1994	A	A	A	A	A	A
Average of 3-Yr Periods	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
10-year Average	A	A	A	A	A	A

Figure 3.1. Box and whisker plots of observed James Tidal Fresh (JMSTF) chlorophyll a concentrations (ug/L) from 1985 to 2004. 'All Values' includes all single observations, 'Monthly Means' is the monthly average of all values and 'Annual Means' is the annual means of the twenty years of observations. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from the ten year simulation (N=30).

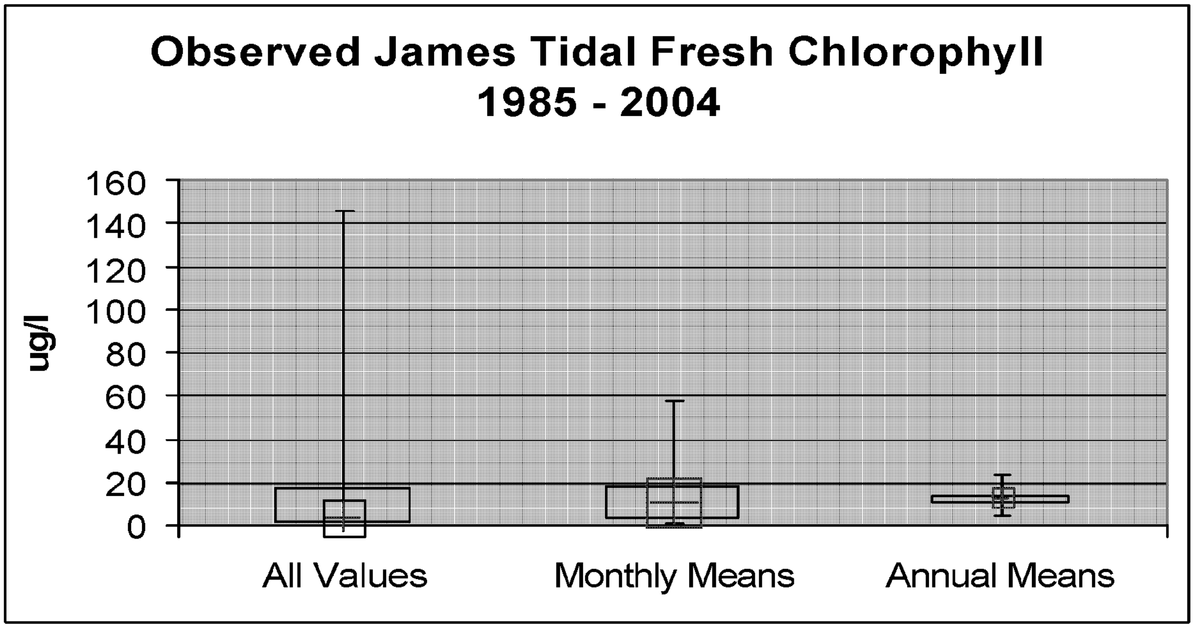

Figure 3.2. Box and whisker plots of observed James Oligohaline (JMSOH) chlorophyll a concentrations (ug/L) from 1985 to 2004. 'All Values' includes all single observations, 'Monthly Means' is the monthly average of all values and 'Annual Means' is the annual means of the twenty years of observations. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from the ten year simulation (N=30).

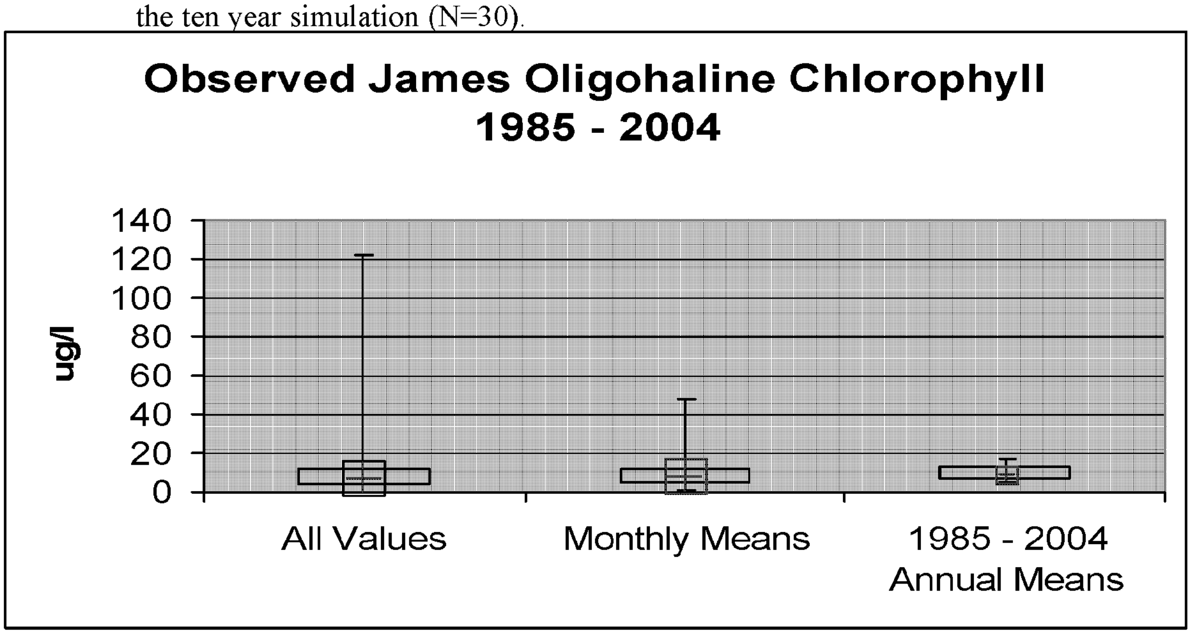

Figure 3.3. Box and whisker plots of observed James Mesohaline (JMSMH) chlorophyll a concentrations (ug/L) from 1985 to 2004. 'All Values' includes all single observations, 'Monthly Means' is the monthly average of all values and 'Annual Means' is the annual means of the twenty years of observations. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from the ten year simulation (N=30).

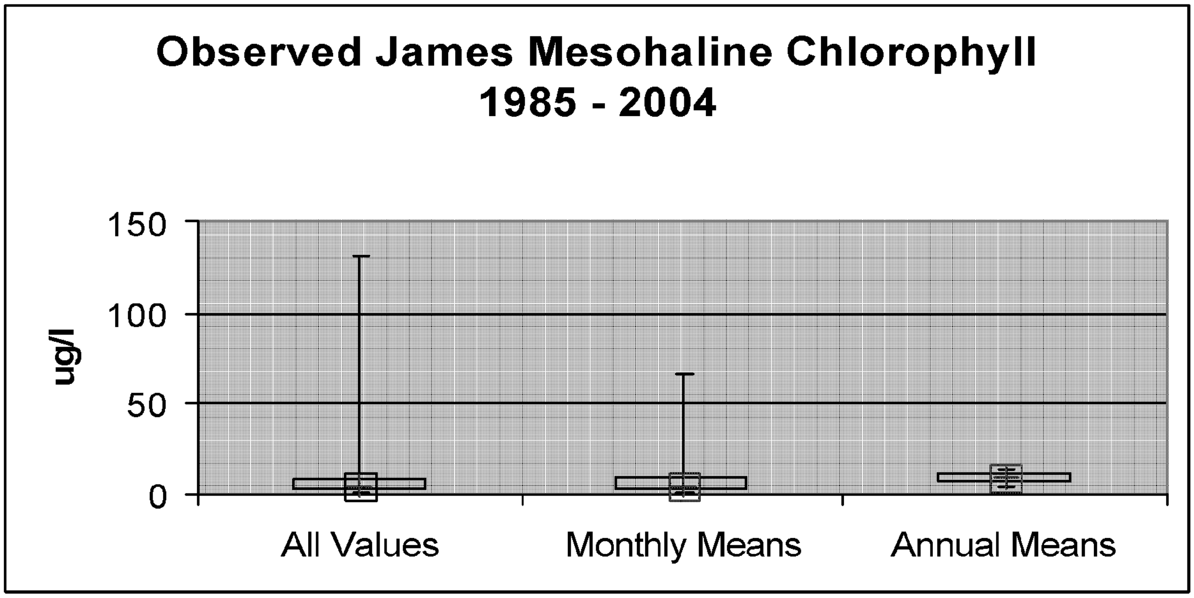

Figure 3.4. Box and whisker plots of observed James Polyhaline (JMSPH) chlorophyll a concentrations (ug/L) from 1985 to 2004. 'All Values' includes all single observations, 'Monthly Means' is the monthly average of all values and 'Annual Means' is the annual means of the twenty years of observations. Shown are the range, the 25th and 75th percentiles, and the median on monthly averages from the ten year simulation (N=30).

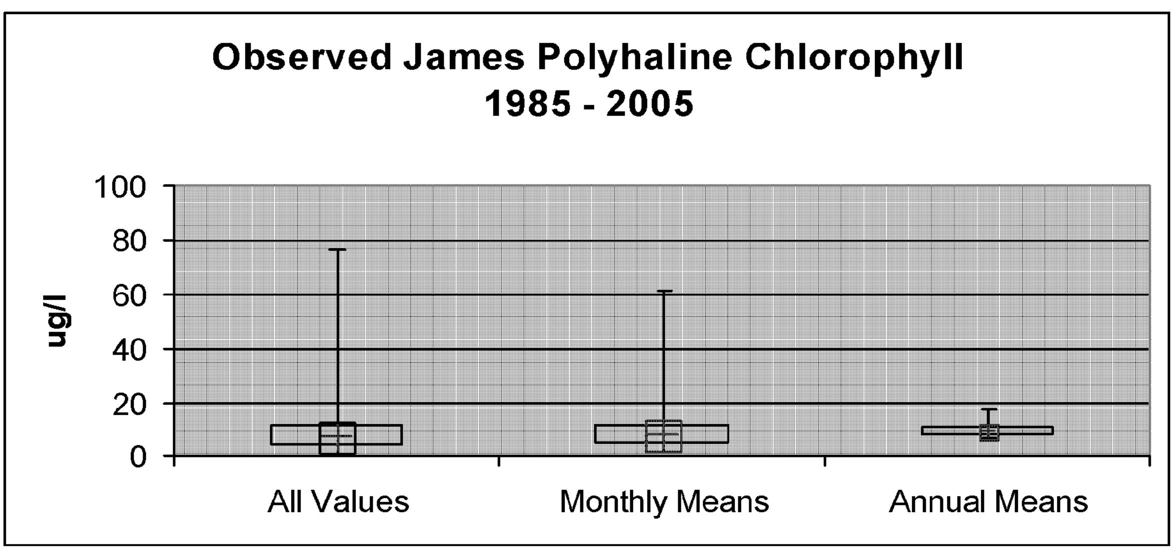

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Figure 3.5. Box and whisker plots of the simulated James Tidal Fresh Upper (JMSTF2) – Spring chlorophyll concentrations from 1985 to 1994. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from ten year simulation (N=30).

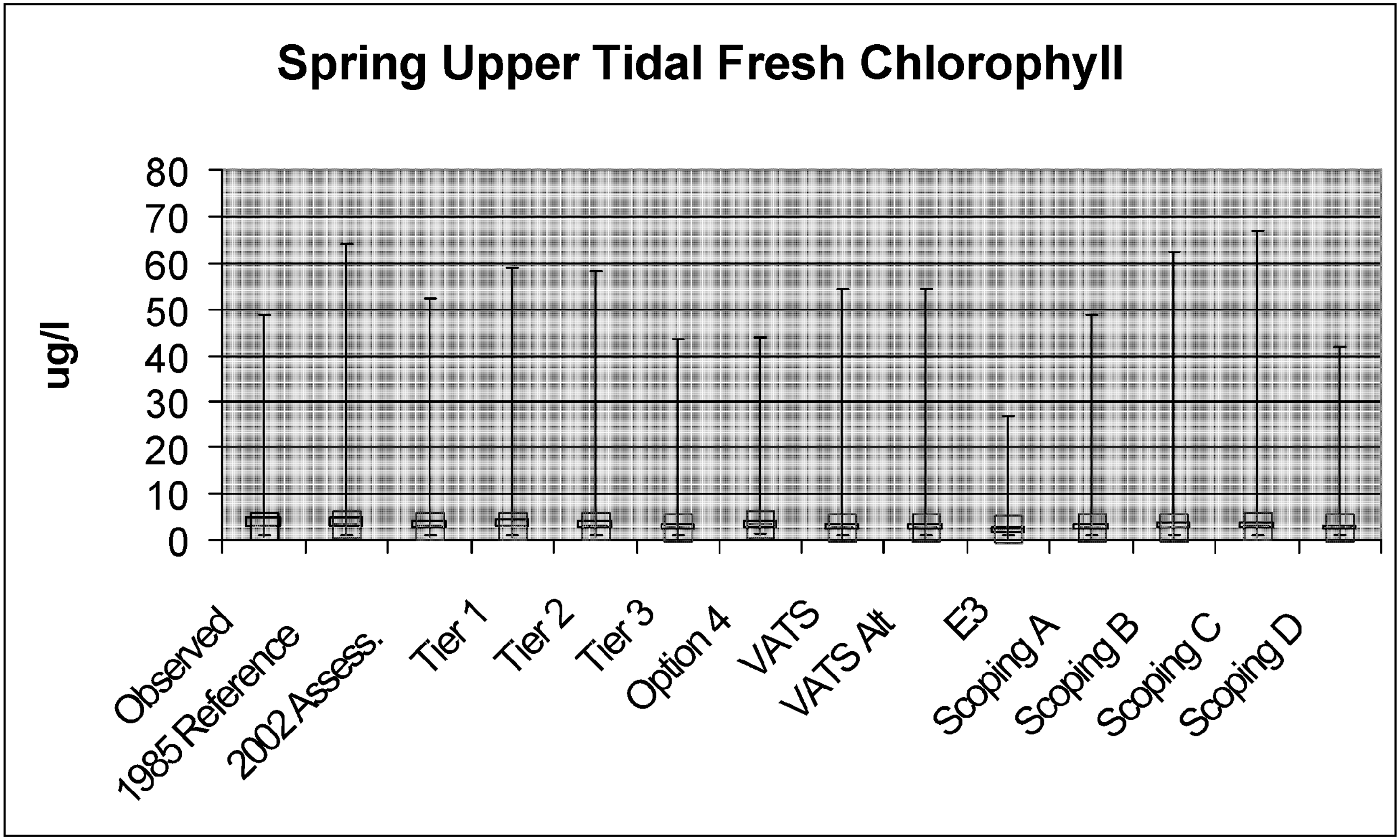

Figure 3.6. Box and whisker plots of the simulated James Tidal Fresh Upper (JMSTF2) – Summer chlorophyll concentrations from 1985 to 1994 Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from ten year simulation (N=30).

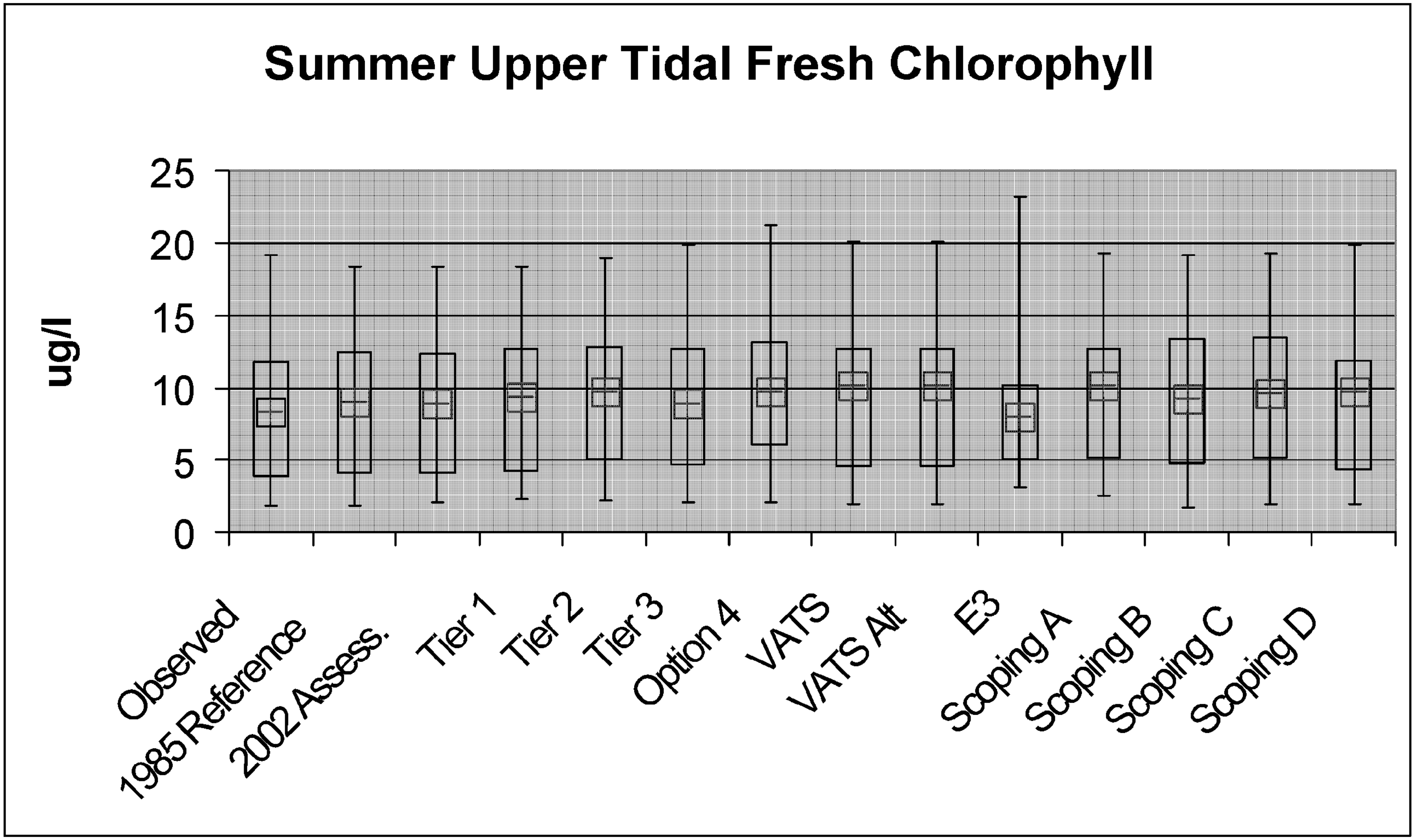

Figure 3.7. Box and whisker plots of the simulated James Tidal Fresh Lower (JMSTF1) – Spring chlorophyll concentrations from 1985 to 1994. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from ten year simulation (N=30).

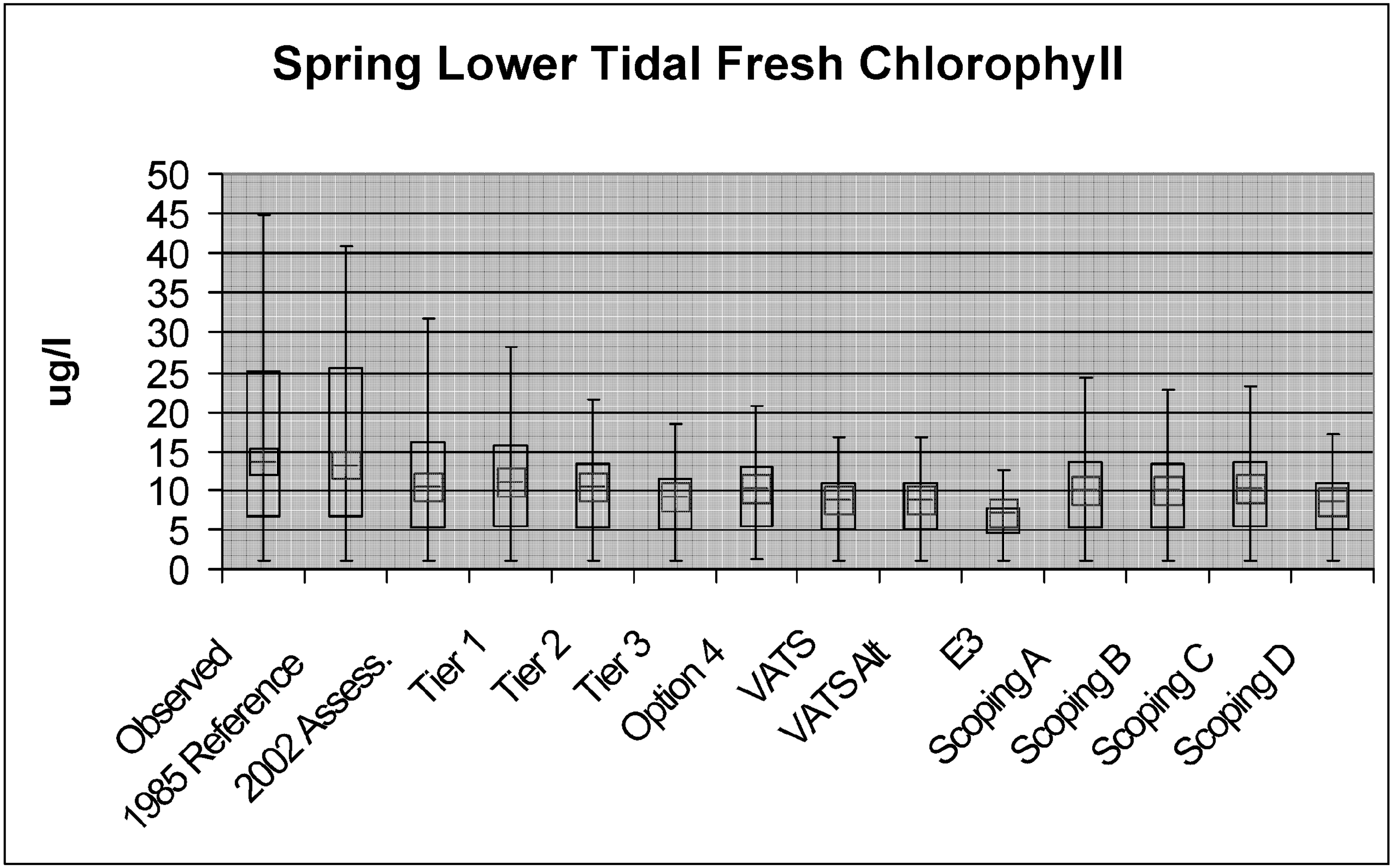

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Figure 3.8. Box and whisker plots of the simulated James Tidal Fresh Lower (JMSTF1) – Summer chlorophyll concentrations from 1985 to 1994. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from ten year simulation (N=30).

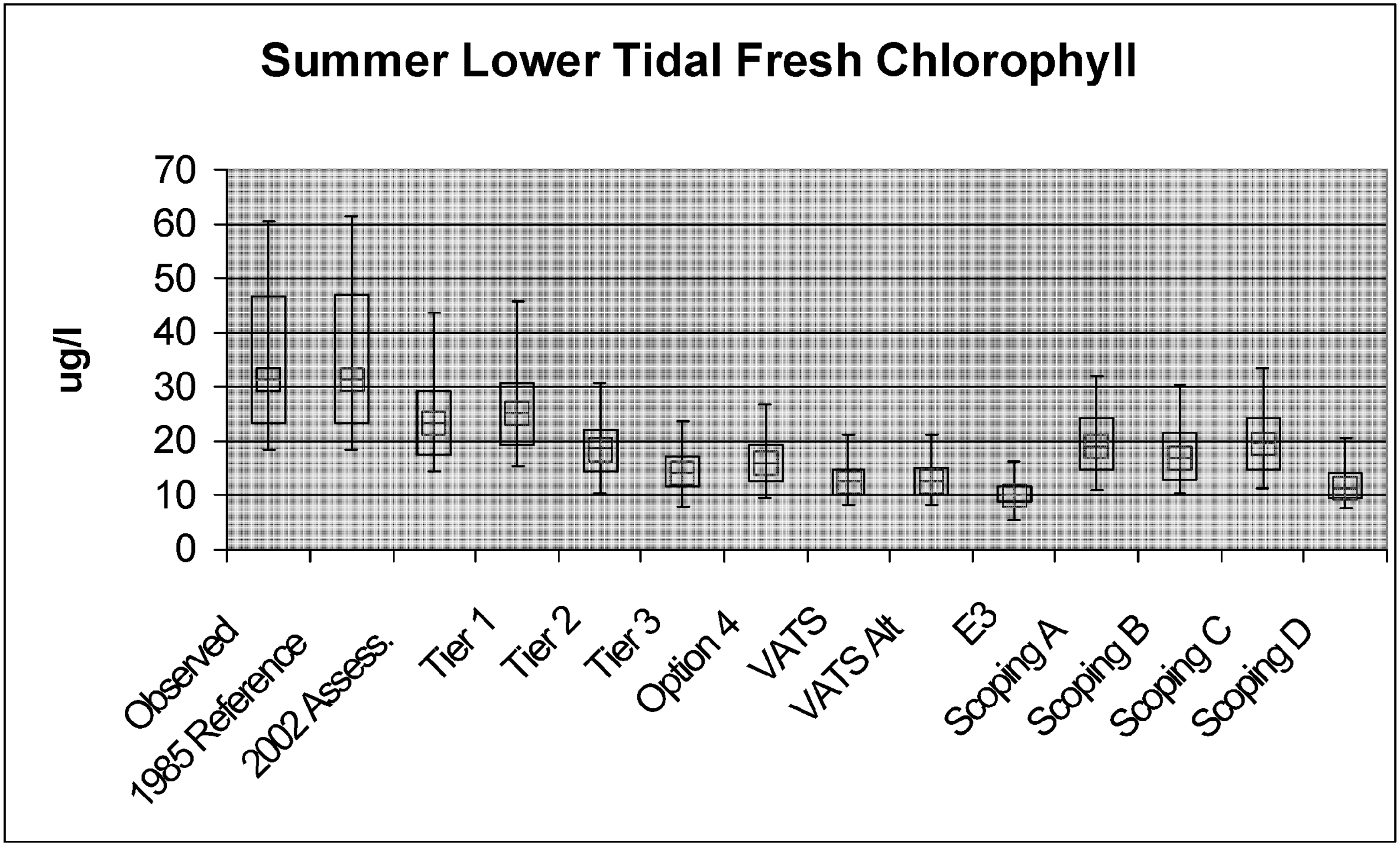

Figure 3.9. Box and whisker plots of the simulated James Tidal Oligohaline – (JMSOH)) – Spring chlorophyll concentrations from 1985 to 1994. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from ten year simulation (N=30).

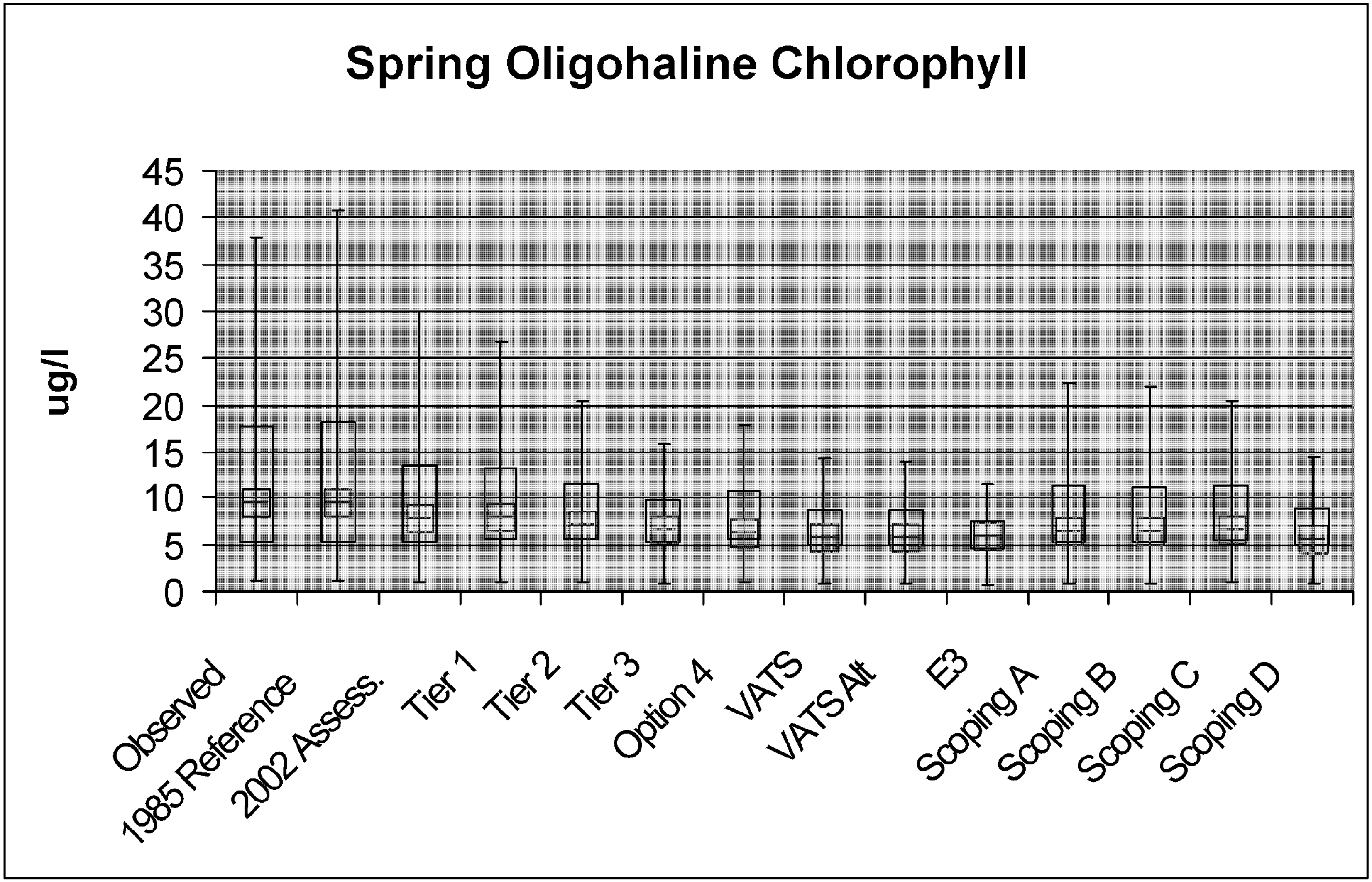

Figure 3.10. Box and whisker plots of the simulated James Oligohaline (JMSOH) – Summer chlorophyll concentrations from 1985 to 1994. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from ten year simulation (N=30).

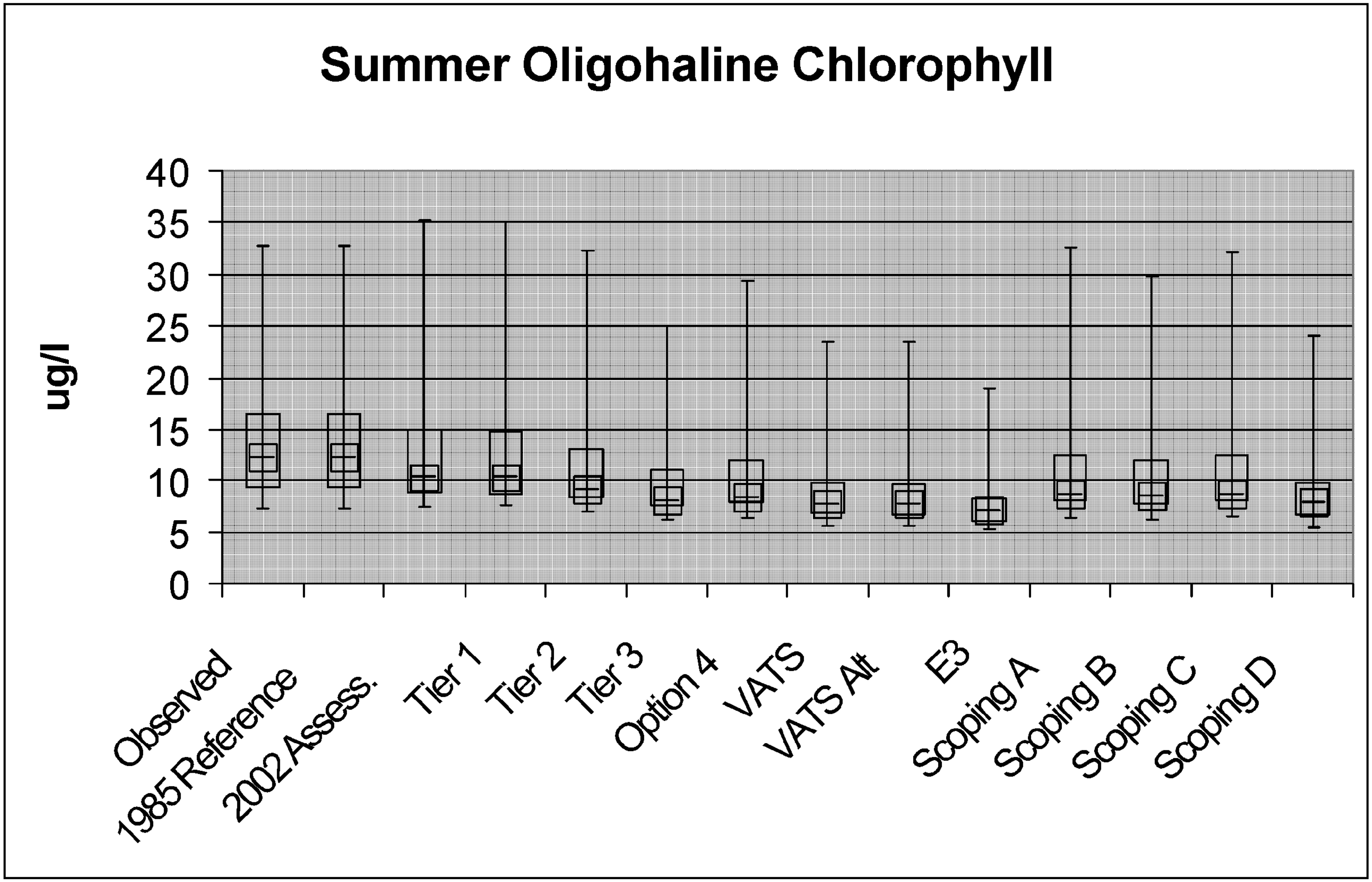

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Figure 3.11. Box and whisker plots of the simulated James Mesohaline (JMSMH) – Spring chlorophyll concentrations from 1985 to 1994. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from ten year simulation (N=30).

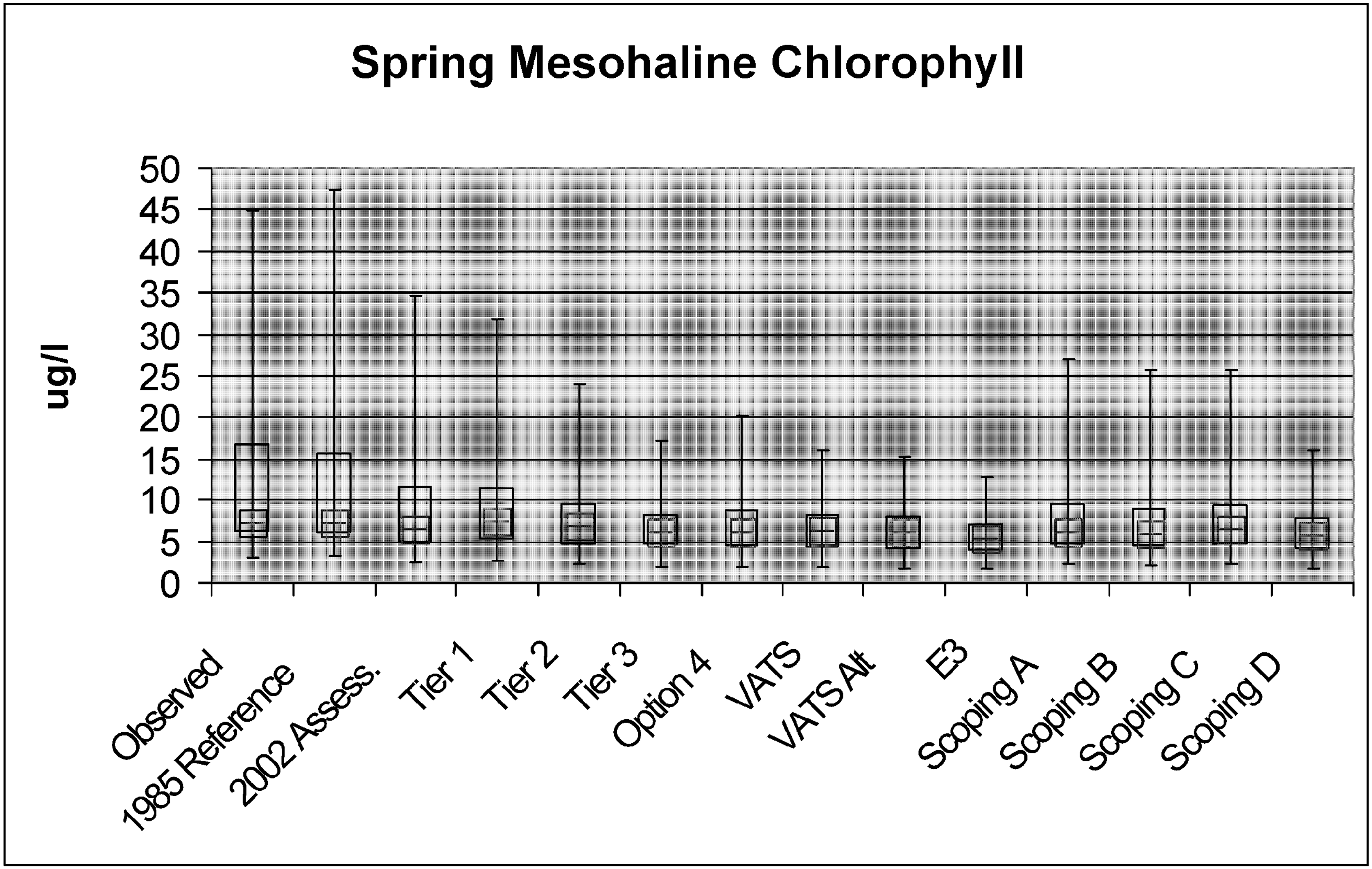

Figure 3.12. Box and whisker plots of the simulated James Mesohaline (JMSMH) – Summer chlorophyll concentrations from 1985 to 1994. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from ten year simulation (N=30).

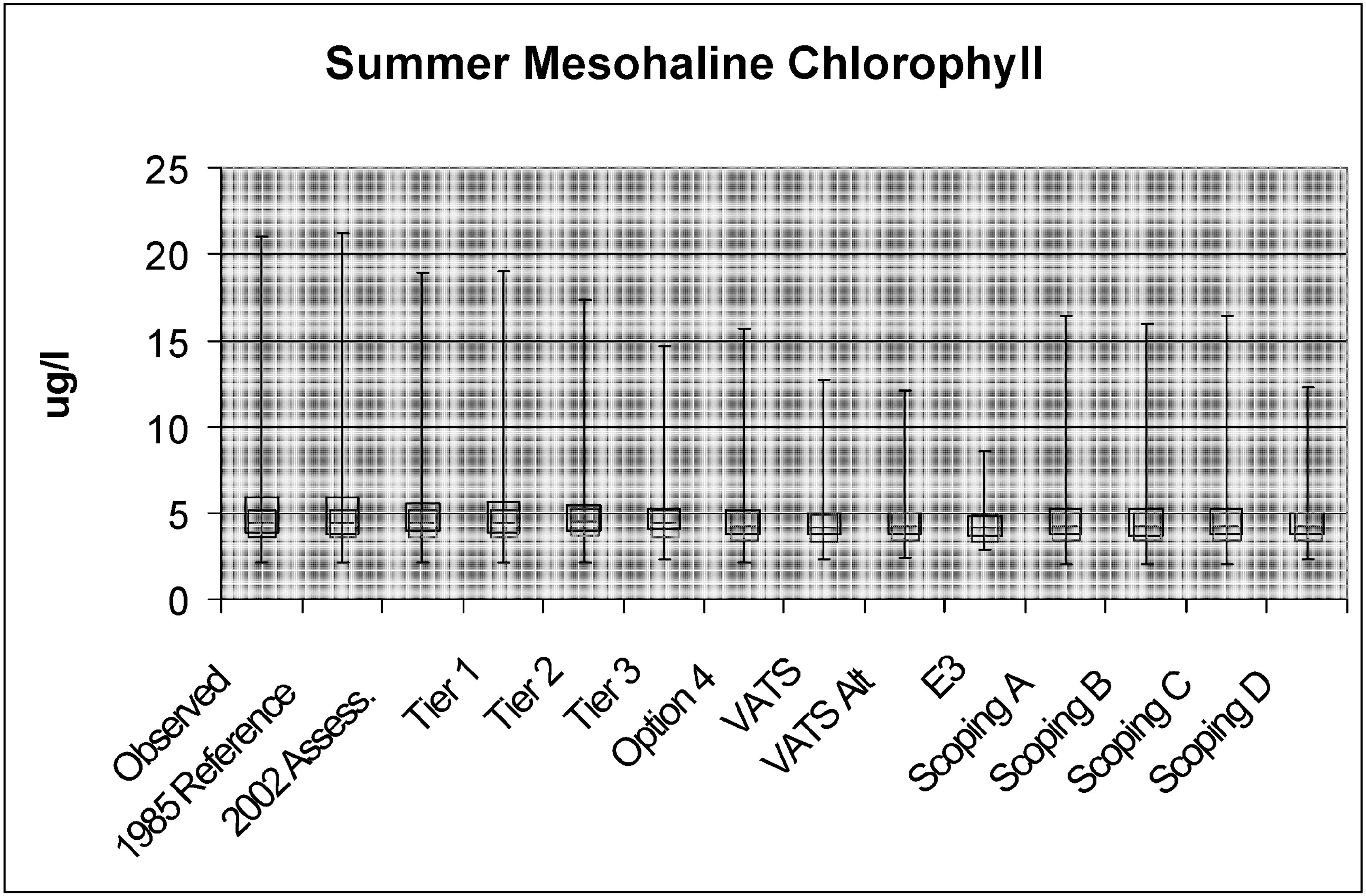

Figure 3.13. Box and whisker plots of the simulated James Polyhaline (JMSPH) – Spring chlorophyll concentrations from 1985 to 1994. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from ten year simulation (N=30).

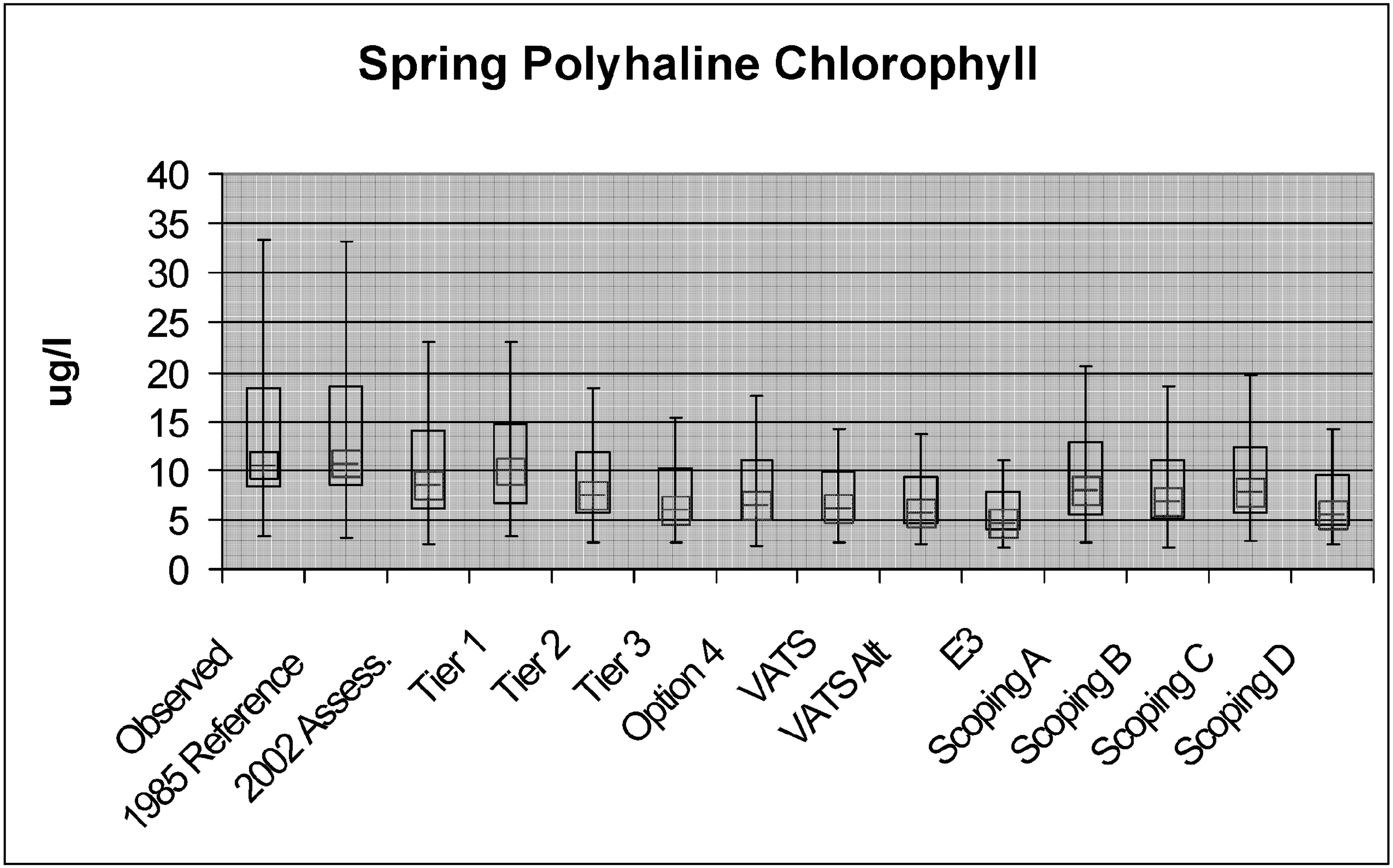

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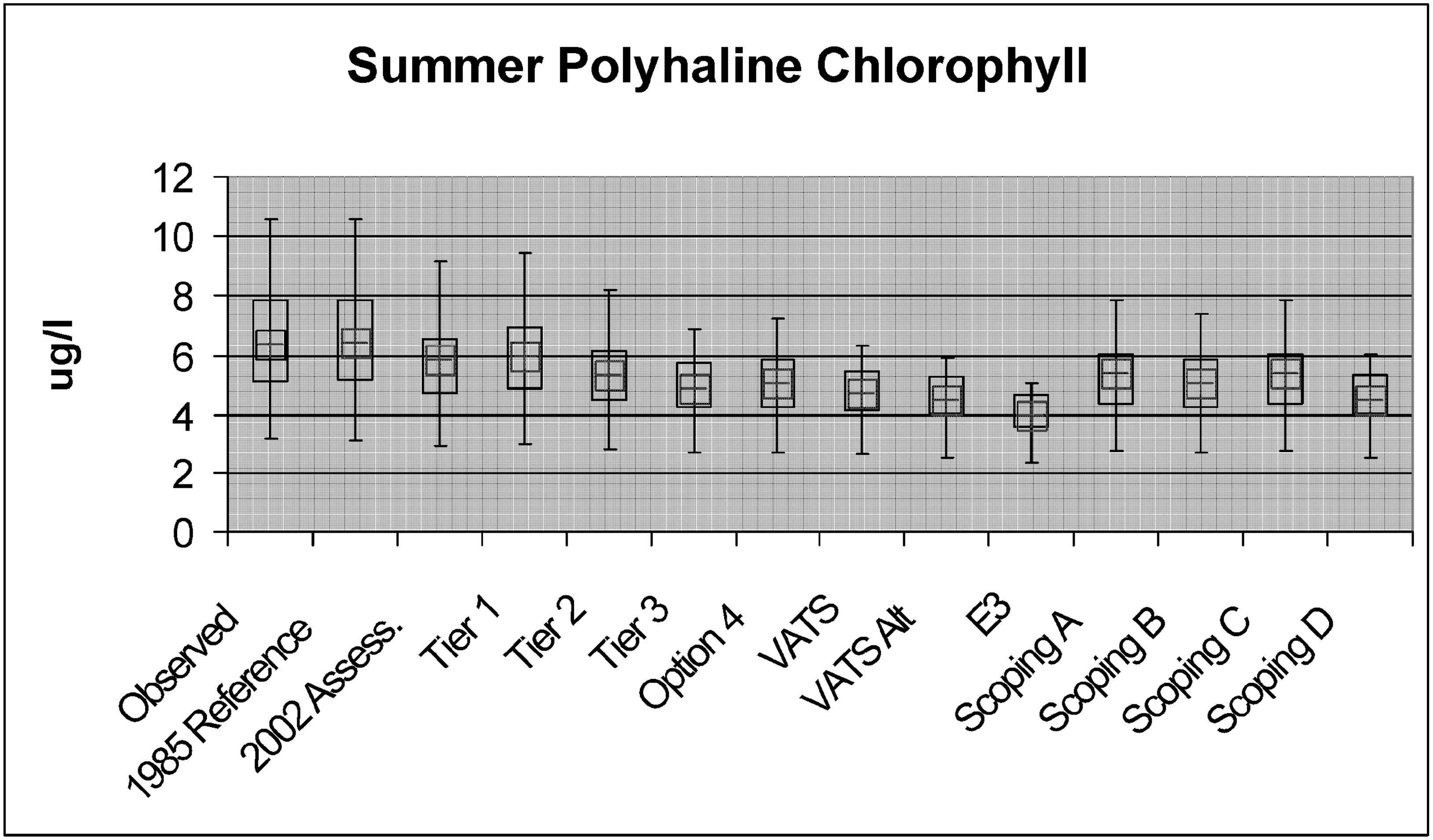
Figure 3.14. Box and whisker plots of the simulated James Polyhaline (JMSPH) – Summer chlorophyll concentrations from 1985 to 1994. Shown are the range, the 25th and 75th percentiles, and the median based on monthly averages from ten year simulation (N=30).



Chapter 4: SUBMERGED AQUATIC VEGETATION RESPONSE TO MANAGEMENT AND SCOPING SCENARIOS

Nutrient and sediment concentrations effect water clarity. The influence of nutrients can be through clarity reduction by algae in the water column, and through algal accumulation (epiphytes) on submerged aquatic vegetation (SAV). To examine the influence of various nutrient and sediment loads in the tidal James River on the SAV resource, the Chesapeake Bay Eutrophication Model estimates of SAV acres is used. Model estimated acres of SAV are derived from the estimated SAV biomass for each scenario. Each scenario biomass is converted to a ratio of the biomass estimated in the 2002 Assessment Scenario, a year where both model estimated and observed mapped SAV acreages are similar. The scenario biomass ratio is then used with the observed 2002 SAV acres to form an estimate of SAV acres for each scenario (Linker *et al.*, 2005). It should be noted that qualitative, not quantitative, improvements should be applied and that feedback effects between SAV abundance and ambient water quality were not modeled (Cerco and Moore 2001).

Since a key determinant of SAV biomass is sediment loads, it is important to know the sediment loads for each scenario. Refer to Chapter 2 for a complete description of each scenario. All management scenarios except for the Option 4, the Virginia Tributary Strategy, and the Virginia Tributary Strategy Alternative scenarios have shoreline sediment input consistent with the year 2000 shoreline management practices. The Option 4 Scenario has shoreline sediment reductions of 20% from the base calibration, and the Virginia Tributary Strategy (VATS) and the Virginia Tributary Strategy Alternative (VATS Alternative) scenarios have shoreline management as specified in the Virginia Tributary Strategy, which is slightly more than a 20% reduction of shoreline loads. All of the scoping scenarios have shoreline management of sediment loads consistent with the Virginia Tributary Strategy sediment loads. All segments of the tidal James River are considered except for the oligohaline (JMSOH). JMSOH has a SAV restoration goal of only 15 acres, too slight an area to estimate with current modeling methods.

The proposed chlorophyll *a* criteria are directly supportive of the adopted water clarity criteria and SAV acreages based on the restoration goals established for each CB segment (U.S. EPA 2003). A summary of the adopted SAV acres and water clarity criteria for the tidal James River segments are summarized in Table 4.1. In the tidal fresh James River, an SAV goal of 1,579 acres was adopted by the Virginia Water Control Board for Submerged Aquatic Vegetation and Water Clarity Standard for the tidal James River (Virginia 2005). Similar goals for the Oligohaline, Mesohaline, and Polyhaline James River were 15, 200, 300 acres (respectively) with 535 acres in the Chickahominy River (CHKOH). However, as stated above, CHKOH was not modeled and results not included. The order of the scenarios presented in this chapter follow the load reductions anticipated from total nitrogen reductions first with the management scenarios followed by the scoping scenarios.

Table 4.1. SAV acres and water clarity criteria adopted into Virginia's Water Quality Standards for the tidal James River by segment and temporal application

Segment	SAV Acres	Water Clarity Criteria (PLW)*	Water Clarity Acres	Temporal Application
JMSTF2	200	13%	500	April 1 – Oct 31
JMSTF1	1,000	13%	2,500	April 1 – Oct 31
APPTF**	379	13%	948	April 1 – Oct 31
JMSOH	15	13%	38	April 1 – Oct 31
CHKOH**	535	13%	1,338	April 1 – Oct 31
JMSMH	200	22%	500	April 1 – Oct 31
JMSPH	300	22%	750	March 1 – Nov 30

*seasonal average light percentages from Chapter 5 should not be used to assess water clarity attainment.
PLW: percent light through water.
** Note that James River segments APPTF and CHKOH were not included since they could not be estimated by the Eutrophication Model

Source: 9 VAC 25-260 March 2005

Key Findings:

- The model was developed towards light being the major factor limiting submerged aquatic vegetation (SAV).
- Almost all segments show a positive response to SAV from combined nutrient and sediment reductions.
- The highest areas of SAV return to the tidal James River corresponded with the highest nutrient and sediment reductions associated with Virginia Tributary Strategy and Virginia Tributary Strategy Alternative scenarios and the high nitrogen reduction associated with Scoping Scenario D.
- Next best SAV restoration is seen under the Scoping Scenarios A – C indicating the importance of shoreline sediment reductions to SAV restoration (Scoping Scenarios A-C had high degrees of shoreline sediment reduction with lesser nutrient reductions).
- Based on model simulations, the tidal James River water quality standards based SAV acreage goals were not met under any scenario, and only the polyhaline segment met the James River established water quality standards-based acreage goals.

Results:

Eutrophication Model estimates of SAV acreage for all scenarios in the tidal James River are presented in Figure 4.1 through 4.4. Figure 4.1 shows the estimates in the tidal fresh James River. The upper (JMSTF2) and lower (JMSTF1) tidal fresh regions are combined, but does not include the Appomattox (APPTX). Of all the management scenarios, the Virginia Tributary Strategy (VATS) and VATS Alternative scenarios have the best estimated SAV restoration result of about 550 acres each for the tidal fresh region. Since all the scoping scenarios apply the Virginia Tributary Strategy level of sediment reduction, they too provide a positive SAV acreage response, though not as significant as the VATS or VATS Alternative except Scoping Scenario D. Scoping Scenario D has a greater reduction of nutrients and the same level of sediment reduction as the VATS scenarios. This demonstrates the importance of nutrient controls coupled with sediment reductions to foster greater SAV restoration efforts. Despite the combined nutrient and sediment reductions estimated in the tidal fresh James River, SAV acres fall short of the 1,579 acre SAV restoration goal. This indicates sediment and nutrient reductions beyond those implemented in VATS or VATS Alternative may be required to achieve the SAV restoration goal.

Estimated SAV acres for the tidal James River mesohaline (JMSMH) is shown in Figure 4.2. At an estimated SAV response of 15 acres, the VATS Alternative Scenario provides the greatest SAV area of all scenarios followed by VATS and Scoping Scenario D. Both nutrient and sediment reductions associated with these scenarios still fall short of the 200 acres of the SAV goal.

Tidal James River polyhaline (JMSPH) region has an SAV goal of 300 acres. A number of management and scoping scenarios reach this goal. All include sediment reductions at the level of VATS. Those scenarios with significant shoreline erosion controls coupled with the largest TN load reduction reflect the largest SAV acreage increase. This supports the importance of coupled nutrient and sediment reductions toward SAV recovery.

Reference:

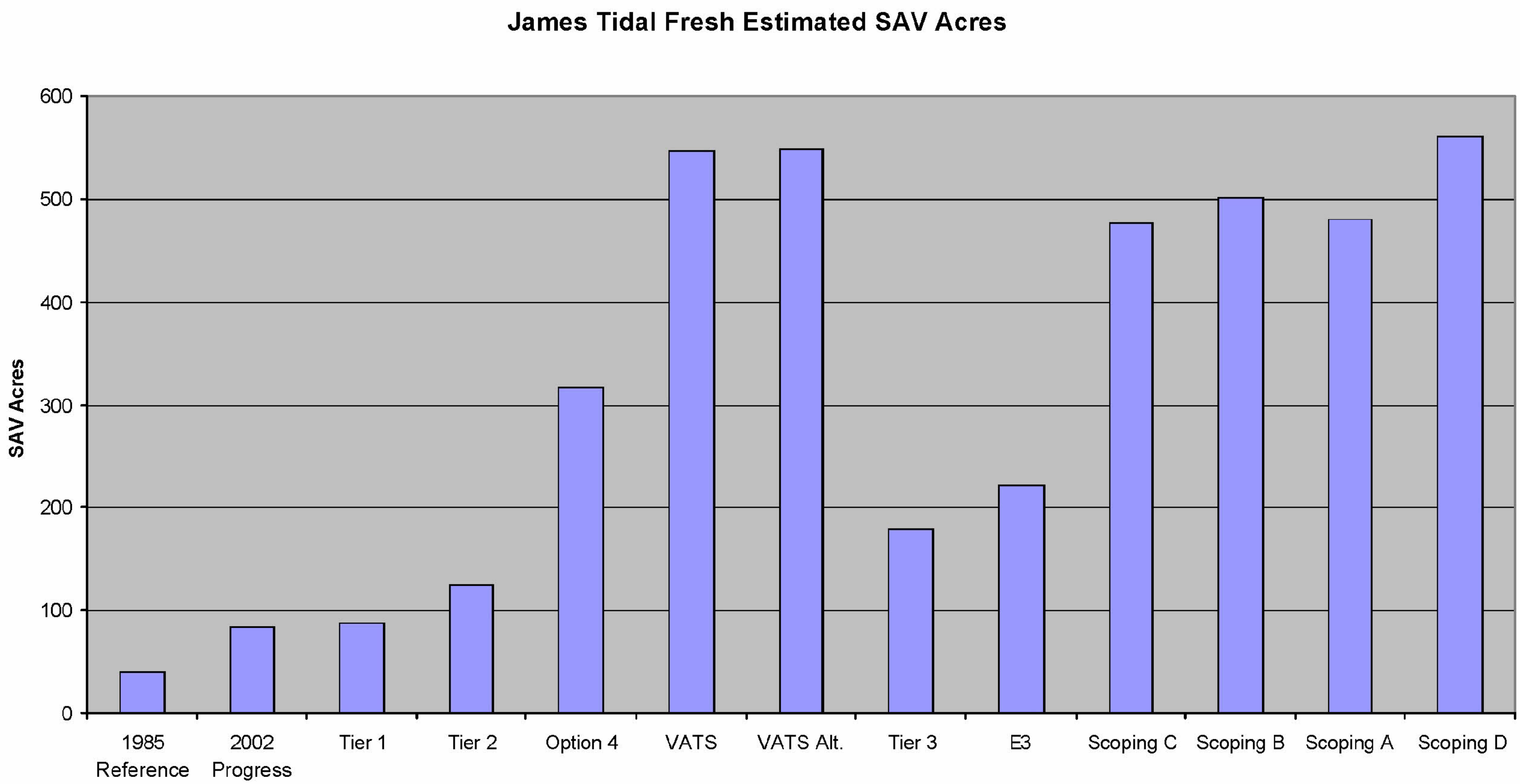
Cerco, CF and K Moore. 2001. System-wide submerged aquatic vegetation model for Chesapeake Bay. *Estuaries* vol. 24(4):522-534.

Linker, L.C., C.F. Cerco, W. M.. Kemp, P Wang, R.A. Batiuk, G.W. Shenk, 2005. *Simulation of clarity and submerged aquatic vegetation in Chesapeake Bay*. In preparation.

USEPA. 2003. *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability*. EPA 903-R-03-004, U.S. EPA Chesapeake Bay Program Office, Annapolis, MD. October 2003.

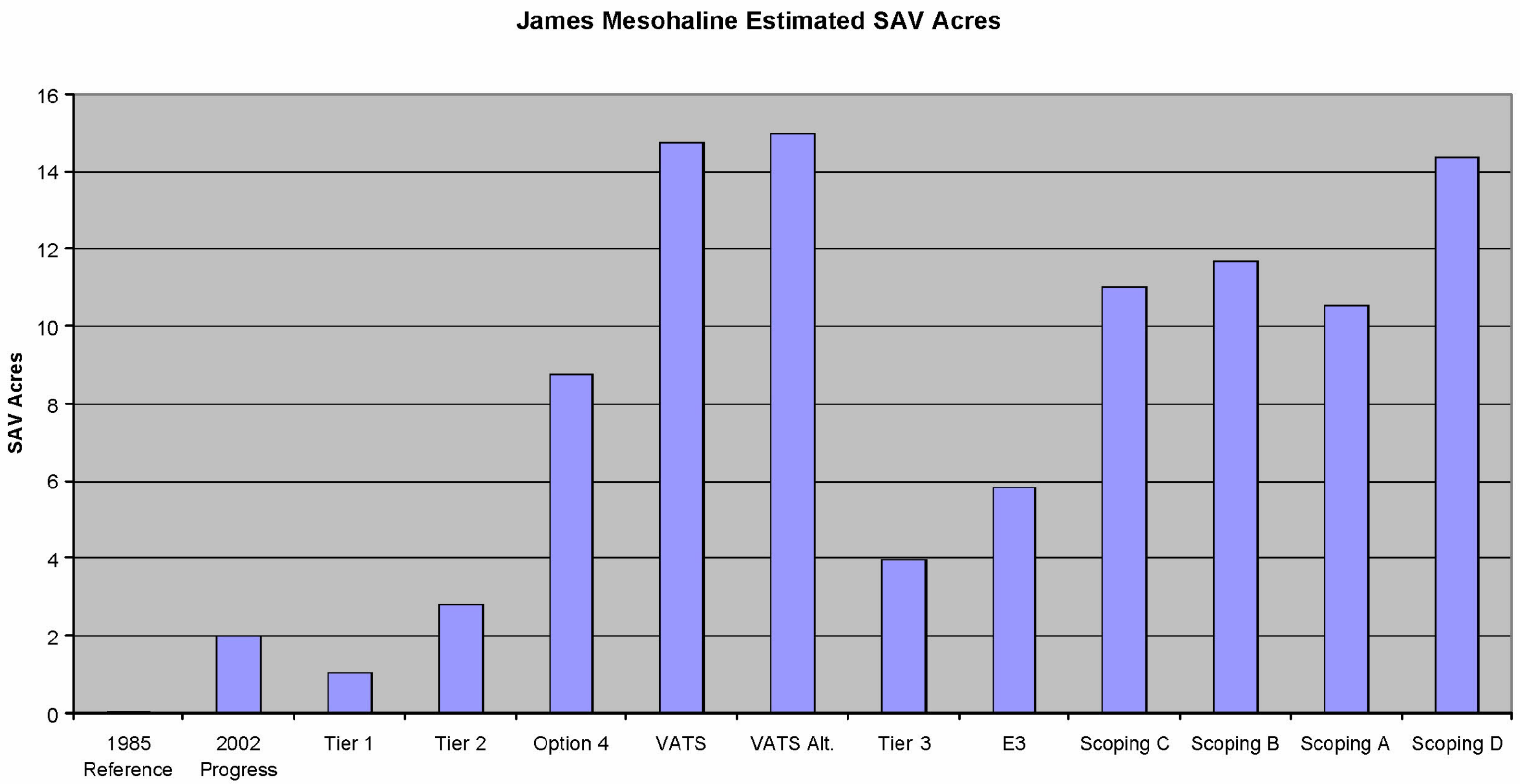
Virginia Water Quality Standards 9 VAC 25-260, March 2005. Surface Water Standards, Surface Water Standards with General Statewide Application.

Figure 4.1. Eutrophication Model estimated SAV acres for all scenarios in the tidal fresh James River (JMSTF)



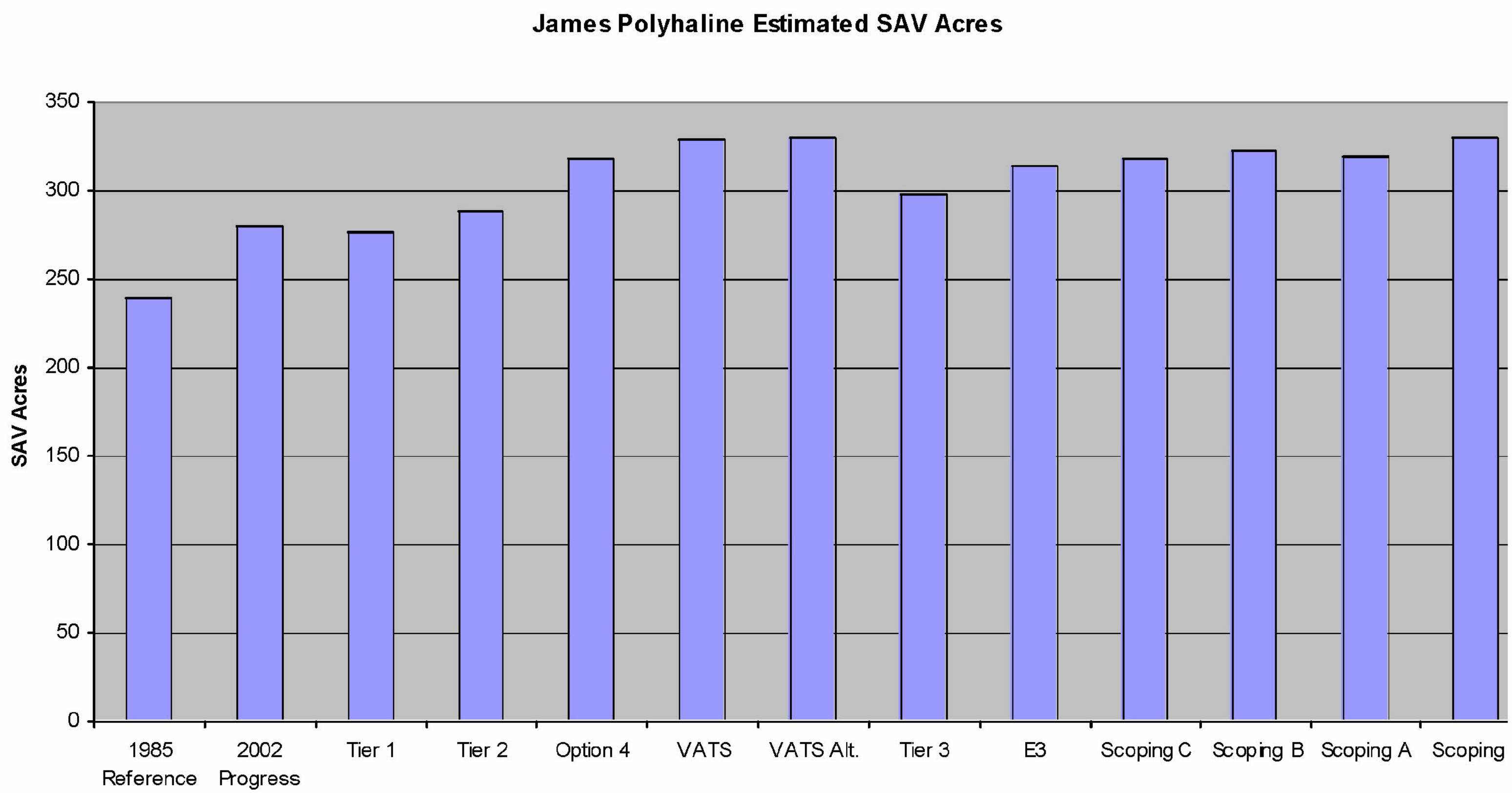
Source: U.S. EPA Chesapeake Bay Program Office

Figure 4.2. Eutrophication Model estimated SAV acres for all scenarios in the tidal James River mesohaline (JMSMH) region.



Source: U.S. EPA Chesapeake Bay Program Office

Figure 4.3. Eutrophication Model estimated SAV acres for all scenarios in the tidal James River polyhaline (JMSPH) region.



Source: U.S. EPA Chesapeake Bay Program Office

Chapter 5: RELATING CHLOROPHYLL CONCENTRATIONS AND STANDARD NITROGEN LOADS

This chapter relates Chesapeake Bay Eutrophication Model simulated chlorophyll *a* concentrations (µg/L) and criteria attainment to a range of total nitrogen loadings (46.9 to 15.2 million pounds of TN) based on thirteen scenarios as requested (Pomeroy 2005a,b). The objective of the Alternatives Analysis described in this chapter was to help evaluate or identify chlorophyll *a* attainment by analyzing a range of options listed in Chapter 2. Specifically, DEQ was requested to determine the attainable chlorophyll *a* concentrations that would result from each modeling scenario using the CFD assessment method (Pomeroy 2005a,b). The chapter is divided into two sections: key findings followed by nitrogen loads (Table 5.1) and requested plots (Figures 5.1 through 5.5). Table 5.1 contains the TN delivered to the tidal James River from point and non-point sources across the basin . The following figures are plots of chlorophyll *a* against TN (million pounds) by season and segment of the tidal James River. Each point simulates the level of criteria achievement based on a ten-year average chlorophyll *a* concentration.

Appendix C contains James TN load to percent (%) non-attainment of the proposed chlorophyll *a* criteria for the tidal James River CB segments for the nine management scenarios (Figures C.1 through C.19). The scoping scenarios have a similar series of graphics (Figures C.11 to C.20). Each figure contains a table of TN loads for each scenario and the percent non-attainment based on the proposed chlorophyll *a* criteria for that segment and season. Figures C.21 to C.40 are plots of the ten-year average TN load related to the model-simulated ten year seasonal average chlorophyll *a* concentrations and light attenuation as percent light through water (PLW) for all scenarios.

For Chapter 5 figures and Appendix C, the reader is cautioned that the use of the James River TN load is a surrogate for the actual, but unknown, James loads. As a tidal tributary to Chesapeake Bay, waters in the tidal James River are a blend of waters and loads from the James watershed as well as waters from Chesapeake Bay, and other tributaries. Using the James TN loads in this sense is to use them as a 'numerical marker', giving an ordinal sense of the relative rank of the different scenarios with respect to nitrogen loads. Resource constraints preclude a complete analysis of the actual loads to the tidal James River, which would change under every scenario.

Key Findings:

- The greatest reductions in chlorophyll *a* concentrations for the tidal James River were associated with greater nutrient reductions such as Tier 3, Virginia Tributary Strategy and Scoping Scenario D. The following summarizes water quality responses in the James River segments based on the ranges of nutrient reductions:
    - Lower tidal fresh (JMSTF1) was responsive during both spring and summer, but greatest during the summer. Spring chlorophyll *a* attainment was between 12 and 22 µg/L for TN loads between 22 and 37 million pounds. Summer chlorophyll *a* attainments ranged from 20 µg/L [for loads between 22 and 26 million pounds TN] to above 30 µg/L chlorophyll *a* [for loads from 34 to 47 million pounds TN].

- The oligohaline (JMSOH) chlorophyll *a* achievements changed between seasons with the spring having lower attainment levels than summer over the range of TN loads. For example, summer chlorophyll *a* attainment levels ranged from 21 to 25 µg/L between 22 and 38 million pounds of TN. Over the same TN load, the spring chlorophyll a attainment levels were from 11 to 20 µg/L.
- The mesohaline (JMSMH) was most responsive during spring with chlorophyll *a* attainments between 11 and 13 µg/L below TN loads of 30 million pounds and above 15 µg/L for TN loads greater than 30 million pounds. Summer chlorophyll *a* attainments were less than 12 µg/L across the range of TN loads.
- The polyhaline (JMSPH) showed a similar pattern as the oligohaline with spring chlorophyll *a* attainments less than 14 µg/L below TN loads of 30 million pounds and above 15 µg/L for TN loads greater than 30 million pounds of TN. Again, summer chlorophyll *a* attainment was less than 10 µg/L across the range of TN loads.

- While nutrients were the primary driver of chlorophyll *a* concentrations and sediments the driver for water clarity improvements, almost all segments showed an increase in SAV acreage from combined nutrient and sediment reductions.
  - As shown in Figures C.21 – C.40, light conditions improve with lower chlorophyll *a* concentrations. All scenarios show greater than 22 percent light through water (PLW). Figures C.24, C.27 and C.29 show that at 10-year average chlorophyll *a* concentrations greater than the proposed criteria, PLW are greater than 13 percent, which is suitable for SAV growth. However, these percentages cannot be compared to the criteria of 13 and 22 PLW directly. These figures show the modeled PLW averaged over the shorter chlorophyll growing season (as opposed to the longer SAV growing season) and do not incorporate the CFD analysis. They are presented here only to show the relationship of chlorophyll on PLW.

Results:
In the Appendix, Figures C.1 to C.10 relate the ten-year average James TN load (million pounds) to % nonattainment of the proposed chlorophyll *a* water quality standard for the tidal James River segments for the eight management scenarios. The scoping scenarios have a similar series of graphics (Figures C.11 to C.20).

The best overall attainment of the proposed chlorophyll *a* standard, apart from the currently unattainable E3 Scenario, was with the Virginia Tributary Strategy Scenario Alternative shown in Figures C.1 to C.20. The only scoping scenario that occasionally achieves equivalent results to VATS or VATS Alternative is Scoping Scenario D, a scenario with lower nutrient loads than the VATS or the VATS Alternative.

Figures C.21 to C.40 relate the ten-year average James total nitrogen (TN) load in millions of pounds to estimated average seasonal chlorophyll *a* concentrations (µg/L), and to light attenuation for the CB segments of the James for all scenarios. These plots show both chlorophyll and clarity as PLW improves most under the scenarios of the VATS and the VATS Alternative.

Note that the best response for reducing chlorophyll *a* concentrations is usually from scenarios with greater nutrient reductions including, in decreasing nutrient reduction order, E3, Tier 3, VATS, and the VATS Alternative. Conversely, the best response with respect to light conditions are scenarios with the greatest sediment reductions including the VATS, the VATS Alternative, and the Scoping Scenarios, all with the same VATS level of sediment load reduction.

As requested, the level of attainment under different criteria concentrations of chlorophyll in 1 μg/L increments from 5 μg/L to 40 μg/L is provided (Table C.1 to C.10 based on ten year averages) (Pomeroy 2005b). The actual proposed chlorophyll *a* criteria concentration, determined by living resource needs, is highlighted in each plot. The Virginia Tributary Strategy (VATS) Scenario is second only to the VATS Alternative Scenario in consistently providing the highest estimated level of attainment of all the scenarios, with the exception of the E3 Scenario, a scenario with nutrient reductions judged to be beyond our grasp. Results from the upper tidal fresh James River (JMSTF2) are questionable for several reasons. Model segmentation in this region of the river is limited creating very few data records for CFD analysis. For example during spring, the percent of non-attainment changed little across a broad range of chlorophyll a concentrations under every scenario (Table C.1). In addition, this segment was totally unresponsive to nutrient reductions during the summer (Table C.2).

References:

Pomeroy, C.D. 2005a. Alternative Analysis for Chl STD. email dated February 09, 2005

Pomeroy, C.D. 2005b. Alternative Analysis for Chl STD. email dated April 15, 2005.

Table 5.1. James River basin model estimated total nitrogen (TN) loads for point and non-point sources delivered to tidal waters. Nutrients in million pounds.

Scenario	TN
1985 Reference	46.9
2002 Assessment	37.7
Scoping Scenario A	37.6
Tier 1	37.3
Scoping Scenario C	36.1
Scoping Scenario B	33.8
Tier 2	28.2
Option 4	28.1
VATS	25.4
VATS Alternate	23.9
Tier 3	23.0
Scoping Scenario D	22.6
E3	15.2

Source:Table 2.1

Legend for Figures 5.1 through 5.5.

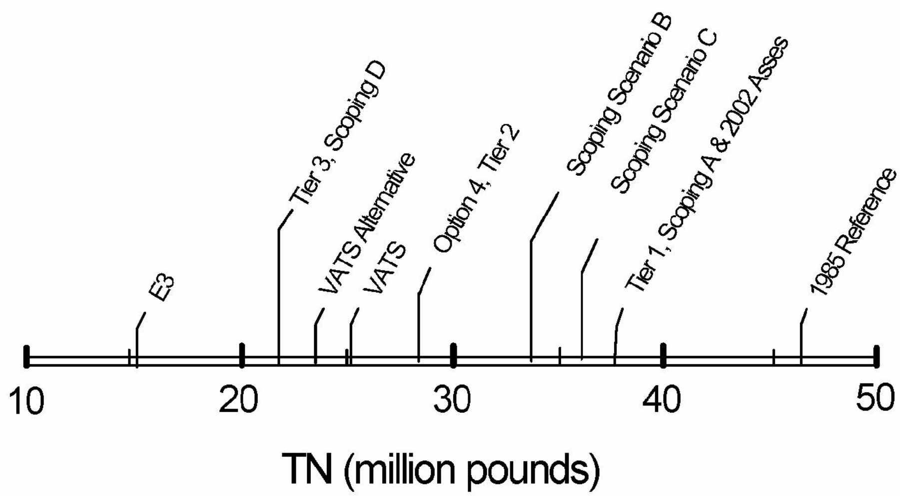


Figure 5.1. Chlorophyll *a* attainment for tidal fresh upper (JMSTF2) based on ten year simulation.

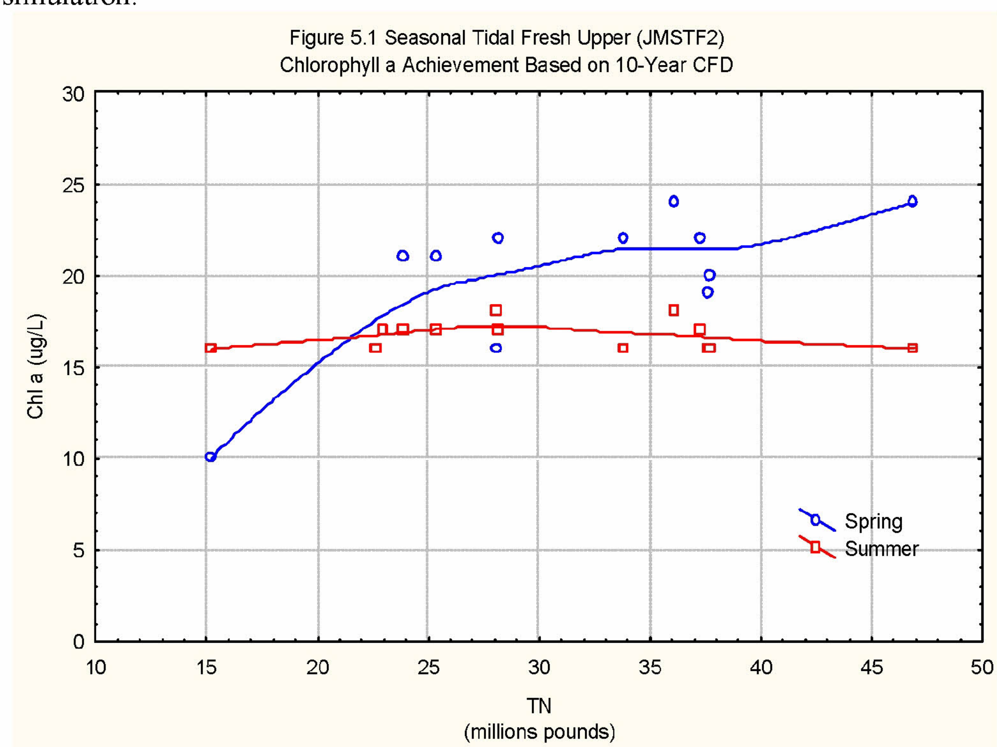


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Figure 5.2. Chlorophyll *a* attainment for tidal fresh lower (JMSTF1) based on ten year simulation.

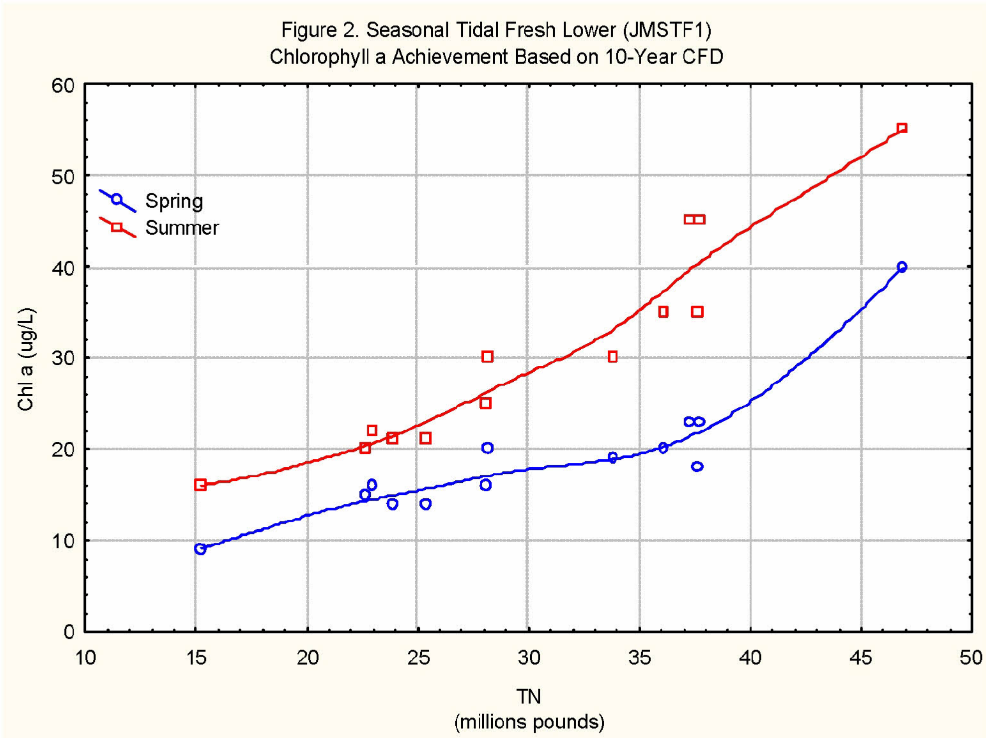


Figure 5.3. Chlorophyll *a* attainment for oligohaline (JMSOH) based on ten year simulation.

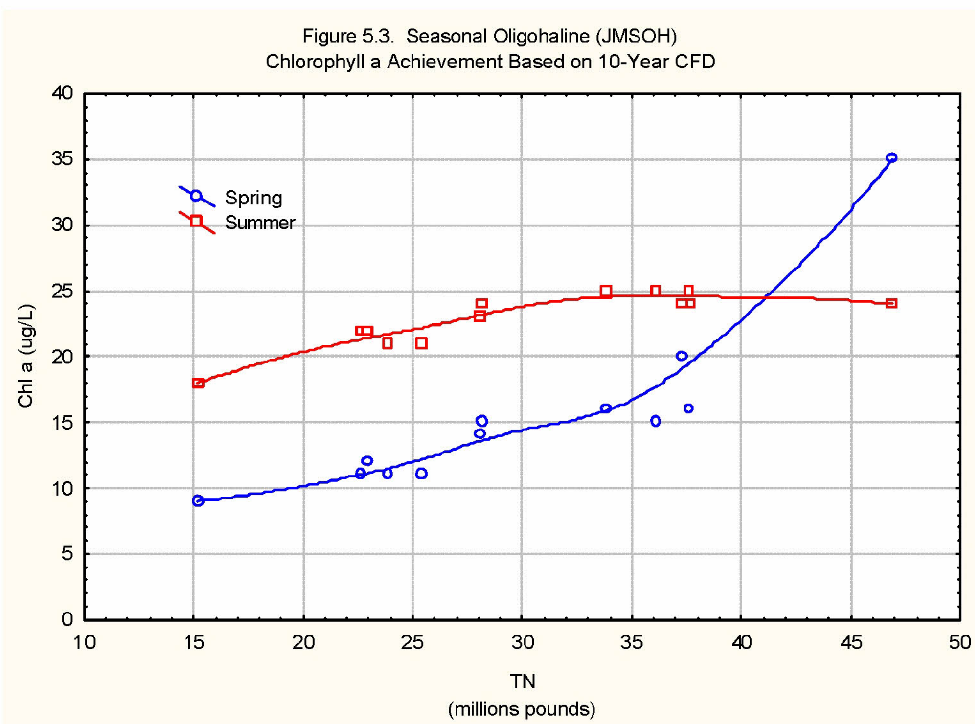


Figure 5.4. Chlorophyll *a* attainment for mesohaline (JMSMH) based on ten year simulation.

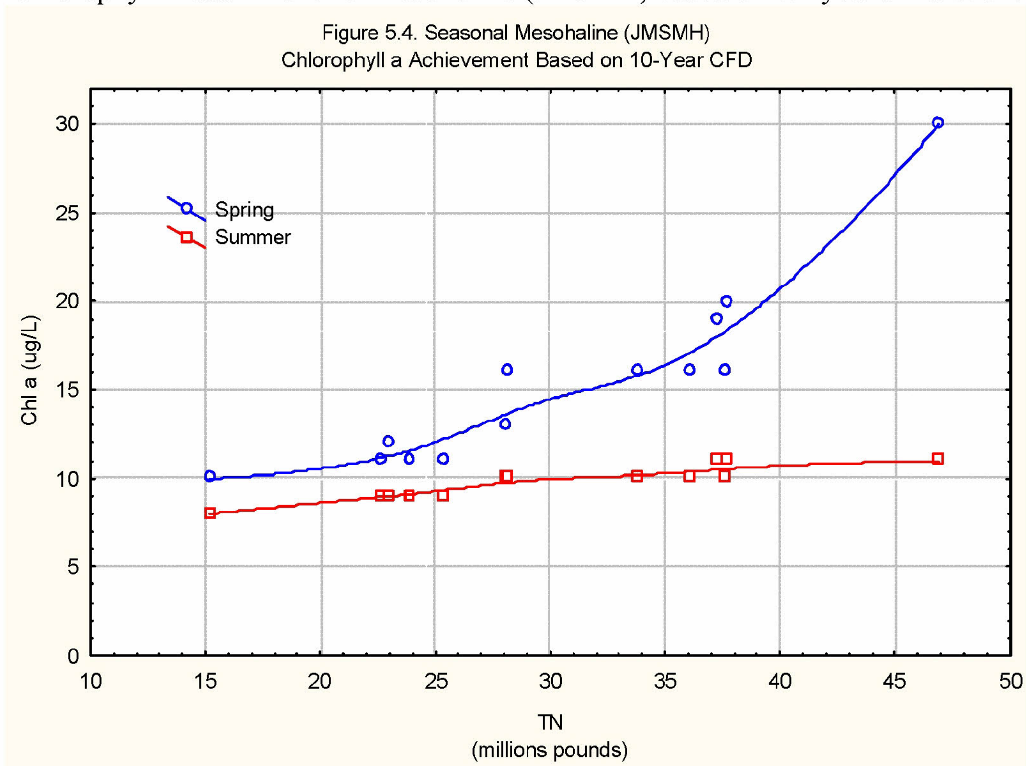
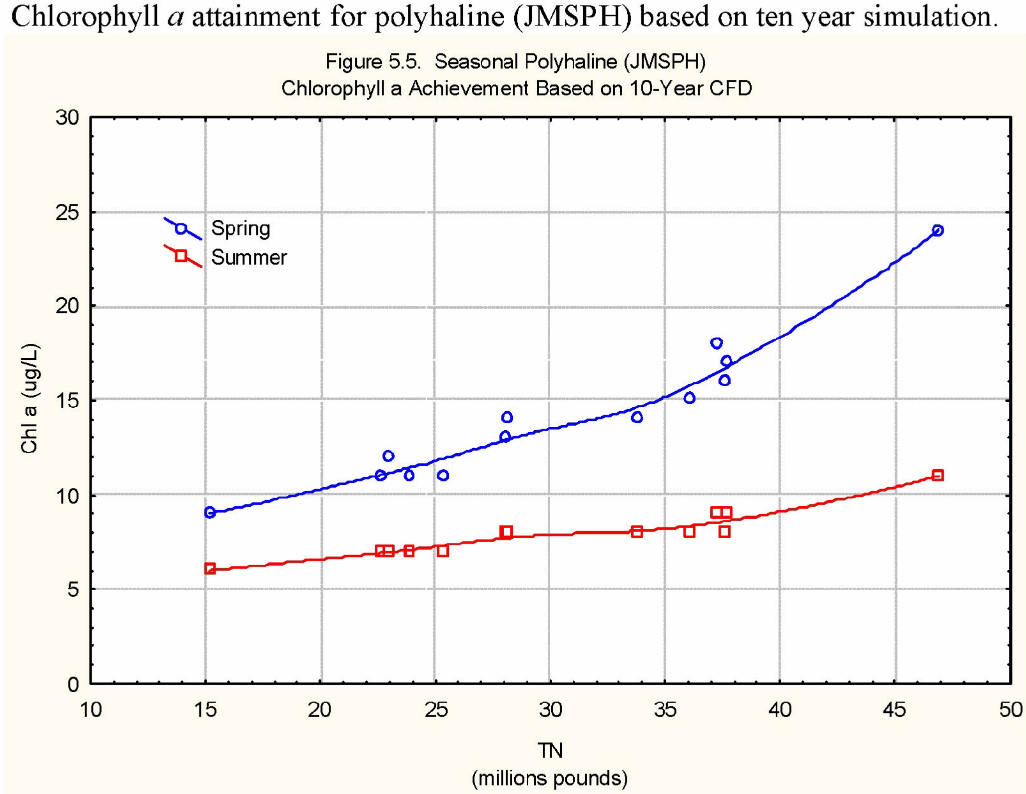


Figure 5.5. Chlorophyll *a* attainment for polyhaline (JMSPH) based on ten year simulation.



Chapter 6: QUESTIONS RELATED TO THE ALTERNATIVES ANALYSIS FOR CHLOROPHYLL-A STANDARDS – WILLIAMS SB 811

In addition to the model scenario evaluation of the Alternatives Analysis presented in Chapters 2 through 5, DEQ was asked a series of questions to be addressed for each alternative (SB 809 Williams, Appendix). The first two questions related to changes in chlorophyll *a* concentrations associated with each scenario as well as anticipated costs associated with each load reduction alternative. The remaining six questions address the benefits related to algal composition, nuisance conditions and food requirements for each alternative scenario. While the Chesapeake Bay Eutrophication Model is capable of simulating a variety of ecosystem responses (Cerco and Noel 2004), it was not designed to provide the detailed costs or benefits analysis described above. Therefore, we were not able to quantify exactly how each scenario (each with its own chlorophyll *a* concentrations) might impact the food web directly based on simulated model output. However, DEQ was able to identify how much lower the chlorophyll *a* concentrations should decline in the tidal James River in response to key scenarios. This information was then compared to reference communities and trophic interactions described in the scientific literature (Buchanan et al. 2005; Marshall *et al.* submitted for publication).

The science behind the proposed chlorophyll *a* criteria relies on basic principals of ecology and research conducted in waters considered least impacted sites with low chlorophyll levels(VADEQ 2004). For example, average summer chlorophyll *a* concentrations in the lower tidal fresh James River under 1985 Reference Scenario would be classified as "impaired" with algal composition consisting of "undesirable" and "nuisance" forms and the risk of blooms greater then 50%. However, as reference chlorophyll *a* concentrations were approached as estimated by various management scenarios (VATS & VATS Alternative), these lower chlorophyll *a* concentrations would be associated with a more "balanced" algal composition represented by fewer "undesirable" and "nuisance" forms and the risk of algal blooms less then 10%. Based on those same ecological principals, we offer the following response to the questions posed.

1. What is the magnitude and percentage reduction in chlorophyll *a* values?

   DEQ Response: *The results of this analysis are presented for the management scenarios in Table 6.1a (based on Table 3.1) and the scoping scenarios in Table 6.1b (based on Table 3.2).*

2. What is the total and incremental coast of the load reduction alternatives?

   DEQ Response*: As suggested by VAMWA from Senator Williams (SB 809 (Williams) Alternatives Analysis for Chlorophyll–a Standards), the alternatives analysis are presented as progressively decreasing nutrient loadings compared to chlorophyll a concentrations as opposed to progressively increasing costs compared to chlorophyll a concentrations. Further communications between DEQ and VAMWA (March 30 emails to Chris Pomeroy from Alan Pollock) recommended that the graphs represent the levels of criteria attainment for each of the scenarios using the CFD based methodology included in the recently adopted standards (9 VAC 25-260-185.D). Tables 5-1 through*

5-10 show incremental levels of nutrient reductions as millions of pounds of total nitrogen (through the thirteen evaluated model scenarios) and the corresponding levels of attainment at different chlorophyll a concentrations. Costs for each of the scenarios are not available and could not be calculated in the period of time this analysis was done. The cost to implement VATS is estimated at $501,000,000 for point sources capital and operational costs, and approximately $4,063,000,000 for non-point source costs.

3. Based on the observed variability of the James River plankton composition with chlorophyll-*a*, what is the expected shift in algal composition?

DEQ Response: *The tidal James River is nutrient" saturated". Without strong nutrient reductions as simulated under VATS and VATS Alternative, James River remains nutrient "saturated" creating conditions more favorable to undesirable bloom producing algae that out-compete co-existing desirable algae. Anything less will result in smaller shifts toward the desirable plankton composition (more bloom producing algae including HABs or harmful algal blooms will still persist). However, exact shifts cannot be determined. The phase transition from "unbalanced" to "balanced" is not sudden but more of a gradual sift as the "balanced" community of algae out-compete the nuisance, less desirable algal community under more favorable water quality conditions.*

As documented in the scientific literature, attaining chlorophyll a concentrations proposed under the numerical criteria would approach a reference community structure (Buchannan et. al. 2005, Marshall et. al. submitted for publication). Under reference conditions, the algal community is more "balanced" as characterized by lower chlorophyll levels, more stable community composition (i.e. less bloom frequency, stable proportions of taxonomic groups, and low biomasses of bloom forming species) and healthier cells with less phaeophytin and lower chlorophyll: carbon content. Achieving the reference community levels will also lead to less "undesirable or nuisance aquatic plant life" as evidenced by fewer cyanobacterium and less "red tide" dinoflagellate biomass (Marshall et. al. submitted for publication). Unfortunately, higher levels of chlorophyll a in certain segments and seasons (which correspond to scenarios 1985, 2002, Tier 1, Tier 2, others) are indicative of algal bloom conditions and persist due to elevated nutrient conditions

4. Is there sufficient scientific information to project that this shift in algal composition would have a measurable impact on fisheries?

DEQ Response: *Yes, shifts toward more desirable species will affect fisheries in a positive manner. While it isn't possible to measure how much it will improve (e.g. increases in catch of commercial fisheries), basic principals of ecology demonstrate that a balanced algal community is beneficial to higher trophic levels. Published studies for Chesapeake Bay show that food, as measured by algae biomass, would also generally be the same or higher than current levels based on reference conditions if the criteria are met (Buchanan et al. 2005). This means a more balanced phytoplankton community for higher trophic levels to graze. Achieving the chlorophyll a concentrations associated with reference phytoplankton community levels will lead to the following favorable changes in community composition in areas of the tidal James River (from Marshall et al. submitted for publication):*

- *Lower abundance and biomass of undesirable dominant seasonal bloom forming dinoflagellates;*
- *Larger cell size of desirable diatoms;*
- *Lower absolute abundance, percent of community abundance and biomass of undesirable cyanobacteria; and*
- *Lower overall abundance and biomass of summer phytoplankton.*

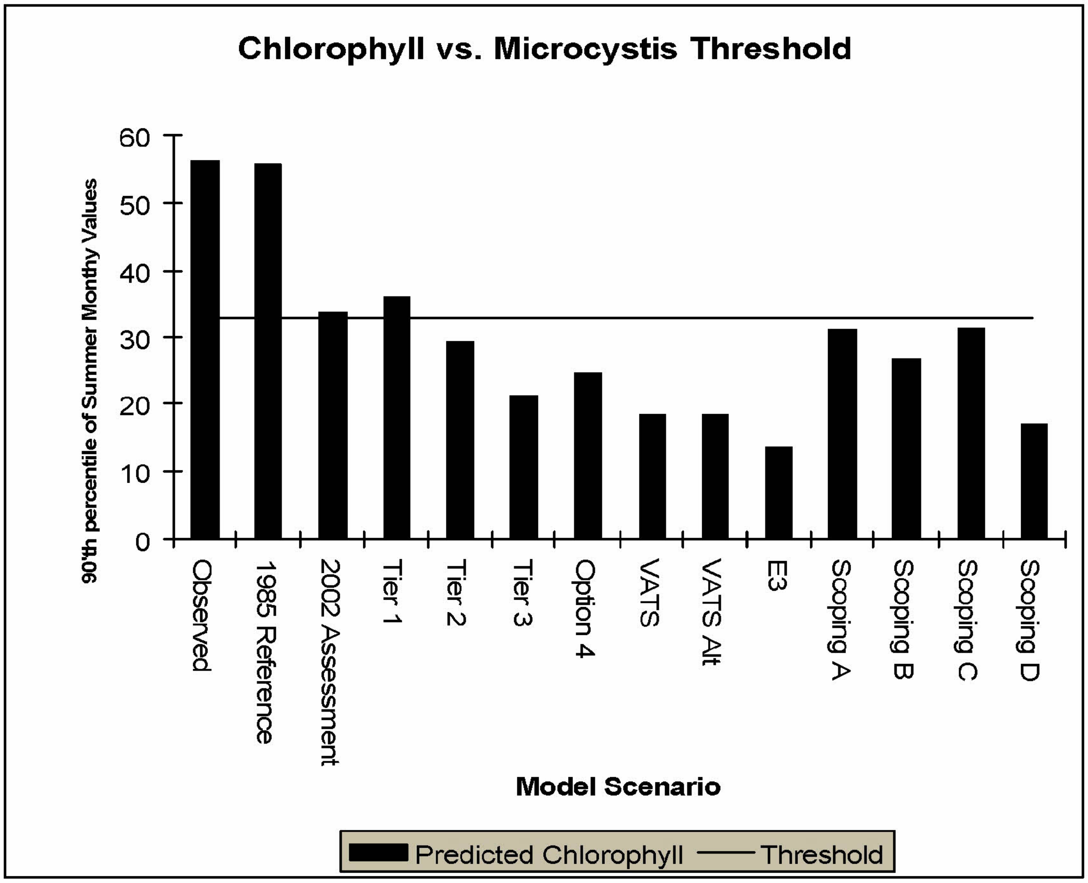
The reduction of undesirable, nuisance and bloom producing algae such as cyanobacteria is desirable. Noxious blooms of colonial cyanobacteria such as Microcystis are well known symptoms of eutrophication and are poor food quality for higher trophic levels. Published scientific literature states that Microcystis and other cyanobacterial blooms can seriously impact the aquatic ecosystem function and health, to aesthetics, and to wildlife, and human health. Such forms can be toxic and large colonial size of Microcystis and other nuisance cyanobacteria are too large to ingest by predators (Lampert 1982; Nizan et al. 1986). Toxicity, lowered assimilation rates, and low nutritional quality of Microcystis cause decreased survival and reproduction of zooplankton and the many commercial and recreational fishes that feed on them (Vanderploeg et al. 2001). In fact, data analysis shows that reductions if chlorophyll conditions to reference conditions will lead to lower biomass of the dominant bloom forming dinoflagellates of H. rotunda, Prorocentrum minimum, and Gymnodinium spp. (Marshall et. al., submitted for publication).

Nuisance and bloom producing algae such as cyanobacteria are not favorable food to mesozooplankton and larval fish. Noxious blooms of colonial Microcystis, Gymnodinium, and others are poor food quality for higher trophic levels. Published scientific literature documents that such forms can be toxic to local fauna and large colonial size and other nuisance bloomers are too large or numerous hampering grazing by zooplankton and larval fish (Lampert 1982; Nizan et al. 1986). Toxicity, lowered assimilation rates, and low nutritional quality of Microcystis cause decreased survival and reproduction of zooplankton, and the many commercial and recreational fishes that feed on them (Vanderploeg et al. 2001).

5. How do the resulting chlorophyll-*a* values relate to thresholds for harmful algal blooms?

DEQ. Response: *As stated in response to question # 4 above, achieving the chlorophyll a concentrations associated with reference phytoplankton community levels will lead to lower abundance and biomass of undesirable dominant seasonal bloom forming algae like dinoflagellates and cyanobacteria. Figure 6.1 shows the 90'th percentile of predicted monthly average values during the summer in the lower tidal fresh segment of the James for each alternative model scenario. Also shown is the 33 ug/l upper threshold at which impacts to higher trophic levels can occur (USEPA 2003). Total nutrient loads must be reduced to at least Tier2 (or similar) levels to be minimally protective against this threshold. Given model uncertainties and the fact that these predictions are for monthly averaged values (vs. the known short time period of blooms), the Virginia Tributary Strategy Scenarios (VATS and VATS Alternative) seem to provide the best practicable water quality conditions to protect against these harmful algal blooms.*

Figure 6.1. 90'th percentile of predicted monthly average values during the summer in the lower tidal fresh segment of the James for each alternative model scenario.



Though most aquatic systems naturally have blooms (i.e., occasional occurrences of much higher than average conditions), an overabundance of any blooms is considered an indicator of a harmful, imbalance in the planktonic aquatic life community. For purposes of comparison, an algal bloom can be defined several ways: as a chlorophyll a concentration greater than the 95th percentile of the values in the reference condition (Buchanan et al. 2005), as values greater than peak concentrations seen world wide in mesotrophic conditions (USEPA 2003), and as values greater than the proposed Virginia chlorophyll a criteria concentrations. Table 6.2 provides the chlorophyll a thresholds used to determine the frequency of spring and summer algal blooms in the tidal James River (Please note that these thresholds should be compared to levels of attainment based on the CFD as described in Chapter 5, Tables 5.1 to 5.10).

Table 6.2. Chlorophyll a thresholds (µg/L) used to determine the frequency of spring and summer algal blooms in James River. An algal bloom is defined by a chlorophyll a concentration exceeding the threshold.

	Maximal (95th%) of phyto reference community (Buchanan et al. 2005)	Peak ranges for mesotrophic conditions [1]	VA proposed chl-a criteria [2]
Spring			
Tidal Fresh	13.5	17	10/15
Oligohaline	24.6	24	15
Mesohaline	23.8	25	10
Polyhaline	6.4	7	10
Summer			
Tidal Fresh	15.9	17	15/20
Oligohaline	24.4	20	15
Mesohaline	13.5	14	10
Polyhaline	9.2	9	10

[1] Derived from Table V-8, pg. 130, USEPA 2003.
[2] VA DEQ Technical Report, 2004 (revised 2005) (spring/summer)

Table 6.3. Guidelines for safe practice in managing recreational waters according to three different levels of risk

Level of risk [1]	Health risks	Recommended actions
20,000 cells cyanobact/mL or 10 µg/L chlorophyll a with a dominance of cyanobact.	Short-term adverse health outcomes (e.g. skin irritation and gastro-intestinal illness, probably at low frequency)	Post on-site risk advisory signs Inform relevant authorities
100,000 cells cyanobacteria per ml or 50 µg/L chlorophyll a with a dominance of cyanobact.	Potential for long-term illness with some species Short-term adverse health outcomes (e.g. skin irritation and gastro-intestinal illness)	Watch for scums Restrict bathing and further investigate hazard Post on-site risk advisory signs Inform relevant authorities
Cyanobacterial scum formation in bathing areas	Potential for lethal acute poisoning Potential for long-term illness with some species Short-term adverse health outcomes (e.g. skin irritations and gastro-intestinal illness)	Immediate action to prevent contact with scums; possible prohibition of swimming and other water-contact activities Public health follow-up investigation Inform relevant authorities

[1] Expressed in relation to cyanobacterial density and given in order of increasing risk.

Source: WHO 2000.
http://www.who.int/docstore/water_sanitation_health/bathwater/begin.html

6. How do the resulting chlorophyll-*a* values relate to nuisance conditions that might impair recreation?

DEQ Response: *Using data collected from the Chesapeake Bay and Tidal Tributary Monitoring Program at station TF5.5, DEQ found that 72% of the summer samples were at concentrations potentially associated with a risk of short term adverse health outcomes during recreation (Table 6.3). Attainment of the proposed numerical chlorophyll a concentration as estimated under the VATS, VATS Alternative, E3 and Scoping D Scenarios will reduce the frequency of observing these levels. The model does not predict taxonomic composition so the quantitative effect can not be estimated.*

It should be further noted that under current water quality conditions, the risk of algal blooms is greater than 50%, but drops to less than 10% under the proposed numerical chlorophyll a concentrations (based on frequency or risk of algal blooms based on the Phytoplankton Index of Biotic Integrity (Buchanan per. comm.).

7. How do the resulting chlorophyll-*a* values relate to food requirements for adult and larval oysters (higher salinity segments)?

DEQ Response: *It is not possible to relate each of the scenarios chlorophyll a levels to food requirements for oysters. However, the historical records from Colonial times to the mid 20th century document that oysters were abundant and easily supported by food concentrations associated with chlorophyll a levels substantially lower than present-day levels. This is similar to the levels reached under the VATS and E3 nutrient load reductions. Nutrient loadings higher than these scenarios maintain eutrophic water quality conditions that favor more undesirable bloom producing algae like cyanobacteria and Prorocentrum minimum. It should be noted that the chlorophyll a concentrations being proposed for the summer numerical chlorophyll a criteria in oyster habitats (i.e. polyhaline segment) are actually above seasonal averages currently observed.*
The scientific literature published for Chesapeake Bay demonstrate that food, as measured by algae biomass, would seasonally be the same or higher than current levels based on reference conditions (Buchanan et al. 2005). So, while chlorophyll a concentrations go down with each management scenario, it favors balanced phytoplankton communities composed of larger, desirable algae. Oysters, while versatile feeders, consume zooplankton and organic detritus as well as algae during various phases of their life cycle (USEPA 1991). Aside from a brief pelagic life stage, oysters remain sessile, firmly attached to the bottom/reef. Once established, suitable planktonic food is necessary for survival and reproduction. Algae high in nutritional value seems to dominate the diets of both resources; both prefer certain algal forms such as diatoms but show physiological stress to others such as certain species of dinoflagellates and cyanobacteria, particularly under high concentrations. These are the undesirable algal species that tend to dominate the phytoplankton community at all scenarios under high nutrient loadings. As the system shifts from nutrient "saturation" to nutrient limitation, co-existing, desirable algae can better compete against the highly opportunistic, undesirable bloom producers.

In addition, DEQ conferred with scientists at the Virginia Institute of Marine Science (VIMS) and Virginia Commonwealth University (VCU). They all came to the same *conclusion –the concentrations in the proposed criteria will provide more than enough algal food for the oysters as well as striped bass, largemouth bass and menhaden (the upper trophic level consumers). Data analysis by VCU concluded that suspended matter in the tidal James River is rich in its algal carbon fraction and its phosphorus and nitrogen content. All three metrics exceeded values reported for consumer thresholds. This means that suspended food particles in the James River are so rich in carbon, phosphorus and nitrogen that it is unlikely that even a 50% reduction from current chlorophyll a levels would result in dietary limitations to upper level consumers (Bukaveckas 2005). In a May (2005) letter to DEQ, Dr. Roger Mann of VIMS indicated that VIMS scientists have concluded that lowered algal levels should not mean poor food supply because species in the wild use food sources other than phytoplankton.*

8. How do the resulting chlorophyll-*a* values relate to mesozooplankton abundance and, relatedly, food requirements for larval fish (lower salinity segments)?

DEQ Response: *Mesozooplankton abundance can not be quantitatively linked to the predicted chlorophyll a concentrations of each scenario. We do know that published reference communities for Chesapeake Bay demonstrate that food, as measured by algae biomass, would generally be the same or higher than current levels based on reference conditions (Buchanan et al. 2005). As discussed in # 4 above, the expected reduction of undesirable, nuisance and bloom producing algae such as cyanobacteria will also be favorable to mesozooplankton and larval fish that may feed upon algae. Noxious blooms of colonial cyanobacteria such as Microcystis are well known symptoms of eutrophication and are poor food quality for higher trophic levels. Published scientific literature documents that such forms can be toxic to local fauna and large colonial size of Microcystis and other nuisance cyanobacteria are too large to eat by potential grazers such as zooplankton and larval fish (Lampert 1982; Nizan et al. 1986). Toxicity, lowered assimilation rates, and low nutritional quality of Microcystis cause decreased survival and reproduction of zooplankton, and the many commercial and recreational fishes that feed on them (Vanderploeg et al. 2001).*

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Table 6.1a. Estimated average chlorophyll *a* (µg/L) concentrations by season and James River segment based on ten year model simulations for each nutrient reduction scenario and the percent change from the 1985 Reference Scenarios. Refer to Chapters 2 and 3 of this report for scenario description and load reductions.

Segment	'85 Ref	'02 Assess	%	Tier 1	%	Tier 2	%	Tier 3	%	Option 4	%	VATS	%
Spring													
JMSTFU	6.82	5.93	13%	6.26	8%	5.99	12%	5.00	27%	5.80	15%	5.32	22%
JMSTFL	16.37	11.89	27%	11.76	28%	10.31	37%	9.04	45%	10.02	39%	8.50	48%
JMSOH	13.74	10.39	24%	9.81	29%	8.52	38%	7.50	45%	8.17	40%	6.88	50%
JMSMH	13.00	10.14	22%	10.07	23%	8.46	35%	7.28	44%	7.87	39%	7.00	46%
JMSPH	14.26	10.79	24%	11.33	21%	9.00	37%	7.54	47%	8.13	43%	7.34	49%
Summer													
JMSTFU	8.86	9.03	-2%	9.44	-7%	9.48	-7%	9.14	-3%	10.00	-13%	9.51	-7%
JMSTFL	34.66	24.49	29%	25.91	25%	19.11	45%	14.74	57%	16.74	52%	12.97	63%
JMSOH	13.85	12.68	8%	12.67	9%	11.65	16%	10.42	25%	11.10	20%	9.32	33%
JMSMH	5.59	5.32	5%	5.33	5%	5.17	8%	4.94	12%	4.92	12%	4.62	17%
JMSPH	6.62	5.90	11%	6.01	9%	5.50	17%	4.99	25%	5.12	23%	4.73	28%

Table 6.1b. Estimated average chlorophyll *a* (µg/L) concentrations by season and James River segment based on ten year model simulations for each scoping scenario and the percent change from the 1985 Reference Scenarios. Refer to Chapters 2 and 3 of this report for scenario description and load reductions.

Segment	'85 Ref	E3	%	Scoping A	%	Scoping B	%	Scoping C	%	Scoping D	%
Spring											
JMSTF2	6.82	3.71	46%	5.19	24%	6.10	11%	6.26	8%	4.80	30%
JMSTF1	16.37	6.65	59%	10.19	38%	10.15	38%	10.45	36%	8.38	49%
JMSOH	13.74	6.06	56%	8.57	38%	8.40	39%	8.41	39%	6.88	50%
JMSMH	13	5.88	55%	8.77	33%	8.29	36%	8.64	34%	6.68	49%
JMSPH	14.26	5.83	59%	9.62	33%	8.56	40%	9.33	35%	6.87	52%
Summer											
JMSTF2	8.86	8.65	2%	9.49	-7%	9.49	-7%	9.82	-11%	9.15	-3%
JMSTF1	34.66	10.56	70%	20.19	42%	17.67	49%	20.32	41%	12.08	65%
JMSOH	13.85	8.06	42%	11.57	16%	11.17	19%	11.55	17%	9.35	33%
JMSMH	5.59	4.33	23%	4.95	11%	4.90	12%	4.95	12%	4.57	18%
JMSPH	6.62	4.01	39%	5.34	19%	5.17	22%	5.33	20%	4.60	31%

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APPENDIX A

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SB 809 (WILLIAMS)
ALTERNATIVES ANALYSIS FOR CHLOROPHYLL-*A* STANDARDS

Introduction

Given questionable benefits, potential ecological detriments, and high costs of the proposed chlorophyll-a water quality standard for the James River, there should be a thorough evaluation of the potential alternatives to support making the best decision possible under the circumstances.

The alternatives analysis should evaluate the benefits, detriments and costs of a range of nutrient loading scenarios and the corresponding predicted chlorophyll-*a* levels. The results would provide vastly better information for setting standards to provide valuable environmental benefits and for helping avoid excessive expenditures for only marginal benefits or no benefit.

More specifically, an alternatives analysis would identify levels of nutrient reduction expected to result in significant benefits (and distinguish them from efforts that show diminishing returns or even adverse effects). It would include an evaluation of how different chlorophyll-*a* levels would be expected to impact oysters, larval fish and other aquatic life uses.

Alternatives to Be Evaluated

The Chesapeake Bay water quality model will be used to simulate a range of nutrient load scenarios and associated chlorophyll-*a* levels in the James River. Model output will be post-processed by season and salinity regime to identify chlorophyll-*a* concentrations that would be attained using the Chesapeake Bay Program's cumulative frequency distribution (CFD) assessment procedure. Specific model scenarios to be evaluated include:

Alternative A – Current Progress (Done)
This alternative represents nutrient loads from the 2000-2004 timeframe. Such a model run should have already been performed by the Chesapeake Bay Program.

Alternative B – BNR Equivalent in the Tidal Freshwater (Update)
This alternative represents a level of nutrient loading consistent with the 2000 James River Tributary Strategy. (Note: This alternative as well as C – E below should also take into account nutrient reductions performed outside the James River basin to meet the new dissolved oxygen (DO) and water clarity standards.)

Alternatives C and D – Intermediate Scenarios (New)
At least two alternatives will be analyzed that represent levels of nutrient reduction intermediate between alternative B (2000 Tributary Strategy) and alternative E (Draft 2004 Tributary Strategy). These alternatives should address the different impacts of loads from the free-flowing, upper tidal and lower tidal portions of the river.

Alternative E – 2004 Tributary Strategy (Done)
This alternative represents the draft 2004 James River Tributary Strategy. This model run has already been performed.

Graphical Presentation & Evaluation of Results

Results of the above alternatives will be evaluated by tabulating and charting the chlorophyll-*a* concentration attained versus the nutrient load and associated cost of implementation. Figures 1 and 2 below provide hypothetical examples of such graphs for the downstream tidal freshwater segment (TF1) (summer) and the polyhaline segment (summer), respectively. (Note: The 90th percentile of the 2000-2004 chlorophyll-*a* data is plotted on these charts to illustrate chlorophyll-a levels representing current conditions, whereas other points charted here are hypothetical values for illustration only).

The chlorophyll-load-cost figures will be interpreted with respect to:

(a) alternatives that would result in significant decreases in chlorophyll-*a*;
(b) alternatives that indicate diminishing returns on expenditures; and
(c) chlorophyll-*a* concentrations relative to both harmful algal bloom thresholds and food requirements for oysters and larval fish.

The following questions will be addressed for each alternative in the sequence ranging from Alternative A (current conditions) to the alterative representing the draft 2004 Tributary Strategy:

1. What is the magnitude and percentage reduction in chlorophyll-*a* values?
2. What is the total and incremental cost of the load reduction alternative?
3. Based on the observed variability of the James River plankton composition with chlorophyll-*a*, what is the expected shift in algal composition?
4. Is there sufficient scientific information to project that this shift in algal composition would have a measurable impact on fisheries?
5. How do the resulting chlorophyll-*a* values relate to thresholds for harmful algal blooms?
6. How do the resulting chlorophyll-*a* values relate to nuisance conditions that might impair recreation?
7. How do the resulting chlorophyll-*a* values relate to food requirements for adult and larval oysters (higher salinity segments)?
8. How do the resulting chlorophyll-*a* values relate to mesozooplankton abundance and, relatedly, food requirements for larval fish (lower salinity segments)?

* * *

Figure 1

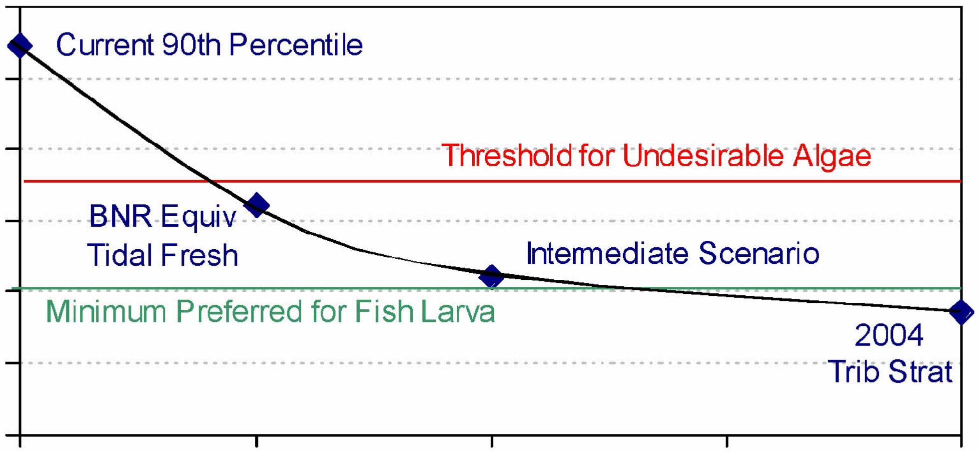
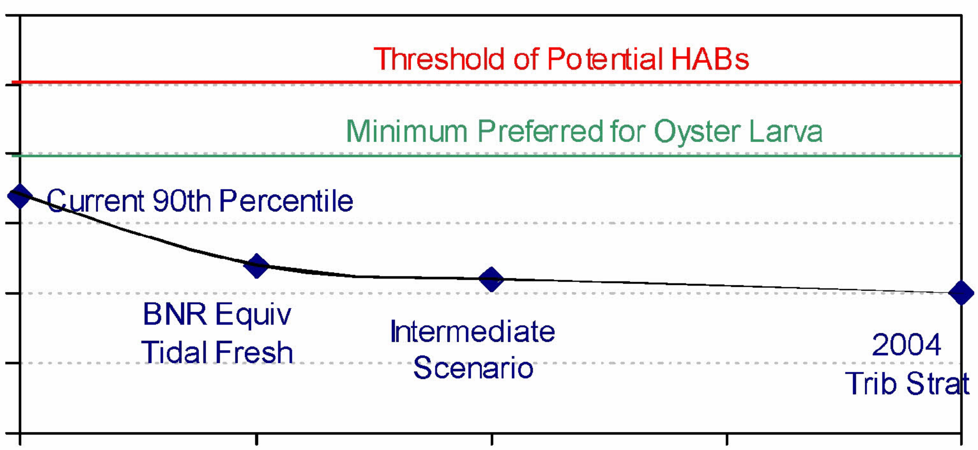


Figure 2



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APPENDIX B

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James Upper Tidal Fresh - Spring Years of 3-yr running avg	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
1985-1987	7.68	5.99	6.60	5.86	4.55	5.21	4.63	4.64	3.14	4.37	5.73	5.91	4.28
1986-1988	7.24	6.22	6.29	5.84	4.88	5.89	4.72	4.72	3.46	4.63	5.78	5.71	4.59
1987-1989	5.97	5.49	5.39	5.12	4.58	5.69	4.33	4.33	3.64	4.43	5.06	4.97	4.34
1988-1990	4.45	4.39	4.12	4.06	3.82	4.87	3.53	3.53	3.08	3.74	4.02	3.86	3.63
1989-1991	4.29	4.05	4.22	4.06	3.77	4.70	3.74	3.74	3.32	3.92	3.96	4.05	3.69
1990-1992	3.79	3.53	3.70	3.55	3.28	4.10	3.28	3.28	2.88	3.41	3.48	3.55	3.22
1991-1993	3.18	3.01	3.17	3.03	2.81	3.51	2.85	2.85	2.54	2.97	2.98	3.06	2.78
1992-1994	8.82	7.41	8.18	7.98	6.24	6.67	7.43	7.44	4.27	6.93	8.44	8.95	6.04
Avg of 3-yr Pds	5.68	5.01	5.21	4.94	4.24	5.08	4.31	4.32	3.29	4.30	4.93	5.01	4.07
10-yr Avg	6.82	5.93	6.26	5.99	5.00	5.80	5.32	5.33	3.71	5.19	6.10	6.26	4.80

James Upper Tidal Fresh - Summer Years of 3-yr running avg	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
1985-1987	11.51	13.38	13.75	13.65	13.15	13.96	13.99	13.99	11.66	13.28	14.03	14.52	13.50
1986-1988	11.63	13.44	13.57	13.78	13.44	14.36	13.84	13.84	12.03	13.29	13.85	14.21	13.39
1987-1989	8.48	9.99	10.02	10.50	10.45	11.13	10.94	10.94	9.79	10.19	10.72	10.80	10.65
1988-1990	8.35	8.99	9.29	9.79	9.72	10.76	9.80	9.80	8.94	9.49	9.78	9.85	9.54
1989-1991	5.89	5.93	6.16	6.37	6.29	7.28	6.67	6.67	6.33	6.41	6.57	6.65	6.47
1990-1992	7.46	7.32	7.89	8.18	8.11	8.99	8.74	8.74	8.86	8.25	8.37	8.48	8.40
1991-1993	8.10	7.73	7.80	7.84	7.65	8.38	7.99	7.99	8.10	8.08	7.70	7.88	7.67
1992-1994	9.20	8.22	8.89	8.76	8.36	8.93	8.70	8.70	8.35	9.01	8.58	9.03	8.34
Avg of 3-yr Pds	8.83	9.37	9.67	9.86	9.65	10.47	10.08	10.08	9.26	9.75	9.95	10.18	9.75
10-yr Avg	8.86	9.03	9.44	9.48	9.14	10.00	9.51	9.51	8.65	9.49	9.49	9.82	9.15

James Lower Tidal Fresh - Spring Years of 3-yr running avg	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
1985-1987	14.54	10.42	10.54	9.16	8.01	8.84	7.57	7.58	6.04	8.88	8.93	9.32	7.40
1986-1988	21.16	13.84	13.84	11.83	10.15	10.79	9.29	9.30	6.90	11.39	11.49	11.92	9.22
1987-1989	20.39	14.79	14.72	12.98	11.33	12.27	10.46	10.47	7.87	12.70	12.86	13.18	10.54
1988-1990	22.26	15.88	15.65	13.66	11.86	12.82	10.86	10.87	8.21	13.42	13.41	13.72	10.90
1989-1991	16.08	12.64	12.44	11.05	9.87	11.23	9.42	9.43	7.64	11.29	11.05	11.32	9.31
1990-1992	15.93	12.11	11.80	10.38	9.21	10.43	8.80	8.81	7.11	10.38	10.29	10.50	8.56
1991-1993	12.38	9.21	8.97	7.94	7.19	8.25	7.09	7.10	5.86	8.14	8.00	8.19	6.82
1992-1994	11.88	9.28	9.08	8.11	7.16	8.11	6.86	6.86	5.43	7.97	8.01	8.19	6.66
Avg of 3-yr Pds	16.83	12.27	12.13	10.64	9.35	10.34	8.79	8.80	6.88	10.52	10.51	10.79	8.68
10-yr Avg	16.37	11.89	11.76	10.31	9.04	10.02	8.50	8.51	6.65	10.19	10.15	10.45	8.38

James Lower Tidal Fresh - Summer Years of 3-yr running avg	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
1985-1987	27.54	18.66	19.94	15.02	11.89	12.87	10.31	10.34	8.68	14.90	12.97	14.88	9.23
1986-1988	36.43	24.87	26.39	18.72	14.31	15.98	12.35	12.39	10.01	19.15	16.77	19.54	11.27
1987-1989	37.08	27.44	28.75	21.67	17.12	19.27	15.17	15.22	12.15	23.00	20.73	23.26	14.47
1988-1990	39.92	30.35	31.65	23.59	18.29	21.14	16.29	16.35	12.73	25.52	22.94	25.92	15.68
1989-1991	31.20	26.68	27.56	22.00	17.53	20.31	15.84	15.88	12.70	23.81	21.49	23.78	15.37
1990-1992	32.26	25.67	26.65	20.70	15.54	18.46	13.82	13.86	11.08	22.25	19.38	22.25	13.11
1991-1993	37.58	26.33	28.12	20.48	15.22	17.88	13.27	13.31	10.85	22.05	18.70	22.04	12.33
1992-1994	40.16	23.79	25.79	17.76	13.03	14.95	11.16	11.20	9.18	19.21	16.06	19.23	10.15
Avg of 3-yr Pds	35.27	25.47	26.86	19.99	15.37	17.61	13.53	13.57	10.92	21.24	18.63	21.36	12.70
10-yr Avg	34.66	24.49	25.91	19.11	14.74	16.74	12.97	13.01	10.56	20.19	17.67	20.32	12.08

James Oligohaline – Spring													
Years of 3-yr running avg	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
1985-1987	8.99	7.58	7.62	7.13	6.63	6.77	6.01	6.00	5.62	6.66	6.65	6.74	5.99
1986-1988	12.71	9.56	9.48	8.62	7.73	8.11	6.96	6.91	6.27	8.13	8.07	8.20	6.94
1987-1989	15.48	11.63	11.38	10.13	8.97	9.63	8.15	8.09	7.08	9.91	9.80	9.90	8.23
1988-1990	21.87	16.03	14.62	12.13	10.21	11.40	9.26	9.13	7.82	12.41	12.16	12.02	9.28
1989-1991	20.04	15.28	13.96	11.56	9.79	10.97	8.93	8.81	7.50	12.04	11.72	11.58	8.98
1990-1992	19.95	14.79	13.22	10.81	9.11	10.27	8.31	8.19	7.06	11.27	10.95	10.79	8.28
1991-1993	11.32	8.62	8.27	7.32	6.60	7.22	6.16	6.12	5.53	7.47	7.24	7.34	6.17
1992-1994	8.46	6.33	6.00	5.39	4.98	5.44	4.74	4.72	4.40	5.53	5.40	5.44	4.73
Avg of 3-yr Pds	14.85	11.23	10.57	9.14	8.00	8.73	7.31	7.25	6.41	9.18	9.00	9.00	7.32
10-yr Avg	13.74	10.39	9.81	8.52	7.50	8.17	6.88	6.81	6.06	8.57	8.40	8.41	6.88

James Oligohaline – Summer													
Years of 3-yr running avg	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
1985-1987	10.45	8.92	8.94	8.10	7.22	7.45	6.35	6.30	5.65	7.63	7.39	7.66	6.26
1986-1988	11.78	10.16	10.13	9.10	8.03	8.35	6.99	6.93	6.23	8.57	8.31	8.60	6.93
1987-1989	14.85	13.90	13.88	13.11	12.21	12.80	11.40	11.37	10.02	13.26	13.00	13.26	11.51
1988-1990	15.41	14.54	14.53	13.74	12.85	13.54	12.08	12.05	10.64	14.07	13.79	14.04	12.25
1989-1991	15.72	15.05	15.09	14.25	13.22	14.04	12.35	12.33	10.84	14.68	14.28	14.63	12.52
1990-1992	15.33	14.55	14.56	13.24	11.36	12.45	9.68	9.61	8.09	13.20	12.50	13.09	9.74
1991-1993	16.72	15.77	15.75	14.20	12.04	13.25	10.17	10.07	8.32	14.07	13.29	13.97	10.18
1992-1994	15.57	14.15	14.13	12.77	10.95	11.96	9.33	9.25	7.63	12.66	12.01	12.58	9.33
Avg of 3-yr Pds	14.48	13.38	13.38	12.31	10.99	11.73	9.79	9.74	8.43	12.27	11.82	12.23	9.84
10-yr Avg	13.85	12.68	12.67	11.65	10.42	11.10	9.32	9.27	8.06	11.57	11.17	11.55	9.35

James Mesohaline – Spring Years of 3-yr running avg	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
1985-1987	8.81	7.39	7.86	6.98	6.40	6.57	6.32	6.06	5.72	7.00	6.56	6.89	5.95
1986-1988	11.71	9.59	9.80	8.51	7.60	7.98	7.36	7.07	6.54	8.72	8.14	8.53	7.04
1987-1989	12.51	10.19	10.27	8.92	7.98	8.44	7.86	7.55	6.89	9.16	8.63	9.06	7.44
1988-1990	16.33	12.79	12.55	10.32	8.65	9.37	8.30	7.94	6.81	10.85	10.20	10.63	7.92
1989-1991	17.96	13.98	13.49	11.02	9.11	10.12	8.71	8.32	6.91	11.58	11.05	11.43	8.33
1990-1992	20.78	15.42	14.72	11.79	9.55	10.80	8.92	8.52	7.02	12.61	11.93	12.32	8.69
1991-1993	14.98	11.36	11.04	9.19	7.84	8.74	7.40	7.10	6.04	9.66	9.20	9.55	7.18
1992-1994	9.32	6.86	6.92	5.84	5.13	5.50	4.92	4.73	4.18	6.02	5.68	5.97	4.68
Avg of 3-yr Pds	14.05	10.95	10.83	9.07	7.78	8.44	7.47	7.16	6.26	9.45	8.92	9.30	7.15
10-yr Avg	13.00	10.14	10.07	8.46	7.28	7.87	7.00	6.71	5.88	8.77	8.29	8.64	6.68

James Mesohaline – Summer Years of 3-yr running avg	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
1985-1987	4.02	4.07	4.08	4.15	4.08	3.94	3.78	3.72	3.63	3.87	3.88	3.88	3.73
1986-1988	4.35	4.27	4.29	4.26	4.14	4.03	3.84	3.77	3.65	4.02	4.00	4.03	3.79
1987-1989	4.85	4.78	4.80	4.76	4.66	4.59	4.41	4.36	4.26	4.57	4.56	4.58	4.38
1988-1990	5.29	5.09	5.11	4.98	4.84	4.81	4.62	4.57	4.46	4.86	4.81	4.85	4.59
1989-1991	5.35	5.19	5.20	5.10	4.99	4.95	4.76	4.72	4.62	4.97	4.93	4.95	4.74
1990-1992	6.10	5.65	5.66	5.35	5.04	5.08	4.72	4.64	4.40	5.18	5.10	5.16	4.67
1991-1993	7.67	7.04	7.05	6.64	6.14	6.25	5.67	5.53	4.97	6.38	6.28	6.38	5.57
1992-1994	7.04	6.49	6.49	6.18	5.78	5.85	5.39	5.29	4.86	5.92	5.86	5.92	5.31
Avg of 3-yr Pds	5.58	5.32	5.33	5.18	4.96	4.94	4.65	4.58	4.36	4.97	4.93	4.97	4.60
10-yr Avg	5.59	5.32	5.33	5.17	4.94	4.92	4.62	4.55	4.33	4.95	4.90	4.95	4.57

James Polyhaline - Spring Years of 3-yr running avg	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
1985-1987	17.35	13.36	13.92	11.05	9.16	10.00	8.79	8.22	6.89	11.92	10.62	11.53	8.38
1986-1988	17.21	12.88	13.61	10.84	9.08	9.81	8.74	8.20	6.91	11.66	10.28	11.23	8.30
1987-1989	15.57	11.45	12.20	9.71	8.12	8.78	7.89	7.40	6.34	10.48	9.17	10.04	7.42
1988-1990	12.59	9.43	10.05	7.89	6.56	7.00	6.54	6.07	5.21	8.54	7.43	8.17	5.94
1989-1991	13.41	10.15	10.58	8.38	6.94	7.47	6.83	6.39	5.47	8.85	7.93	8.55	6.29
1990-1992	14.45	10.73	11.15	8.82	7.32	7.90	7.12	6.66	5.58	9.52	8.50	9.15	6.66
1991-1993	14.42	10.97	11.51	9.28	7.90	8.48	7.61	7.20	6.10	9.78	8.82	9.55	7.20
1992-1994	11.90	8.95	9.48	7.57	6.48	6.94	6.34	5.99	5.07	8.01	7.17	7.88	5.90
Avg of 3-yr Pds	14.61	10.99	11.56	9.19	7.70	8.30	7.48	7.02	5.95	9.84	8.74	9.51	7.01
10-yr Avg	14.26	10.79	11.33	9.00	7.54	8.13	7.34	6.88	5.83	9.62	8.56	9.33	6.87

James Polyhaline - Summer Years of 3-yr running avg	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
1985-1987	6.61	5.69	5.89	5.21	4.64	4.76	4.38	4.18	3.62	5.11	4.87	5.10	4.20
1986-1988	6.33	5.43	5.62	4.98	4.46	4.58	4.27	4.08	3.58	4.93	4.70	4.91	4.10
1987-1989	7.17	6.31	6.43	5.85	5.23	5.42	4.89	4.73	4.08	5.65	5.47	5.62	4.78
1988-1990	7.19	6.39	6.49	5.90	5.27	5.49	4.95	4.77	4.08	5.71	5.53	5.67	4.83
1989-1991	7.34	6.53	6.63	6.05	5.43	5.64	5.10	4.92	4.24	5.86	5.68	5.83	4.98
1990-1992	6.80	6.05	6.16	5.62	5.09	5.27	4.86	4.67	4.05	5.51	5.33	5.49	4.70
1991-1993	6.65	6.05	6.15	5.72	5.27	5.39	5.06	4.90	4.34	5.58	5.43	5.57	4.92
1992-1994	6.10	5.67	5.73	5.45	5.12	5.17	4.91	4.80	4.36	5.25	5.17	5.25	4.81
Avg of 3-yr Pds	6.77	6.02	6.14	5.60	5.06	5.22	4.80	4.63	4.05	5.45	5.27	5.43	4.67
10-yr Avg	6.62	5.90	6.01	5.50	4.99	5.12	4.73	4.57	4.01	5.34	5.17	5.33	4.60

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APPENDIX C

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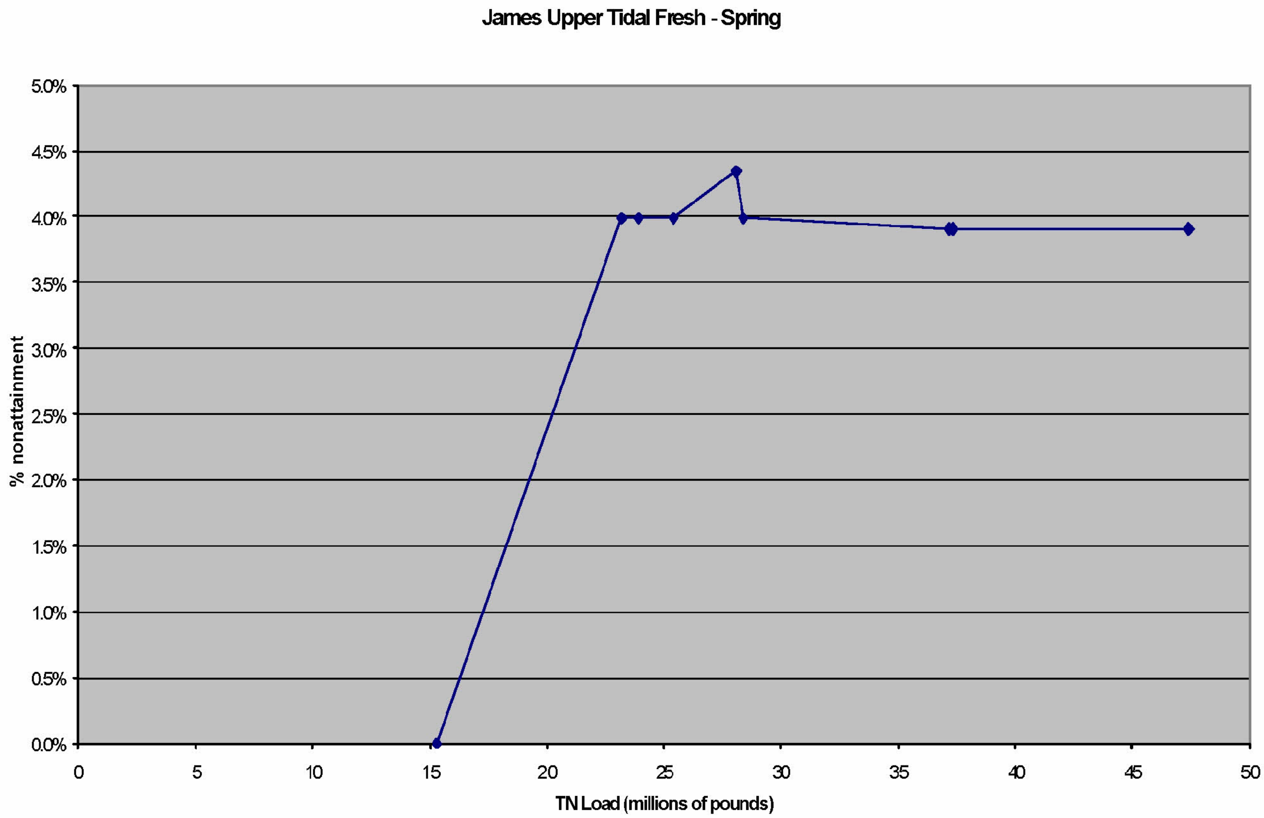
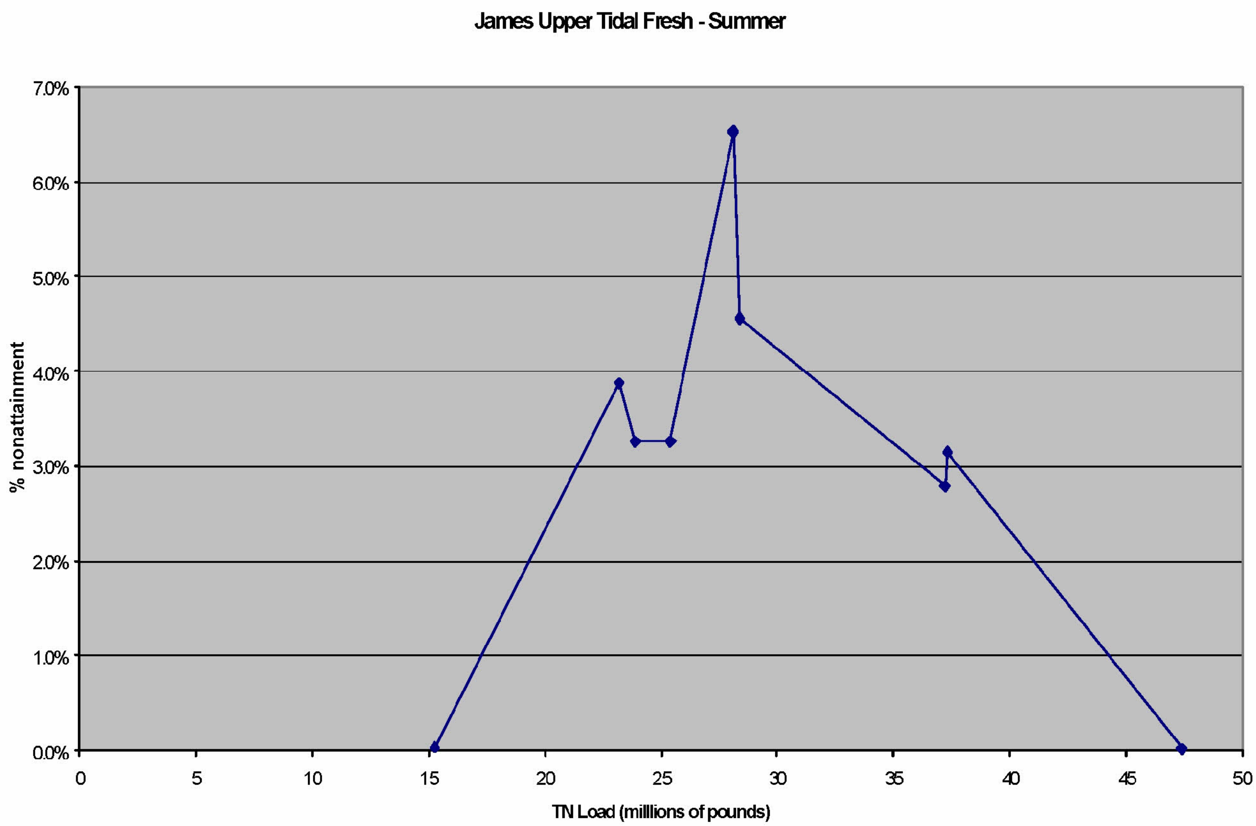
Figure C.1. Ten-year average TN load (million pounds) related to the model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Upper Tidal Fresh (JMSTF2) spring period for the management scenarios.



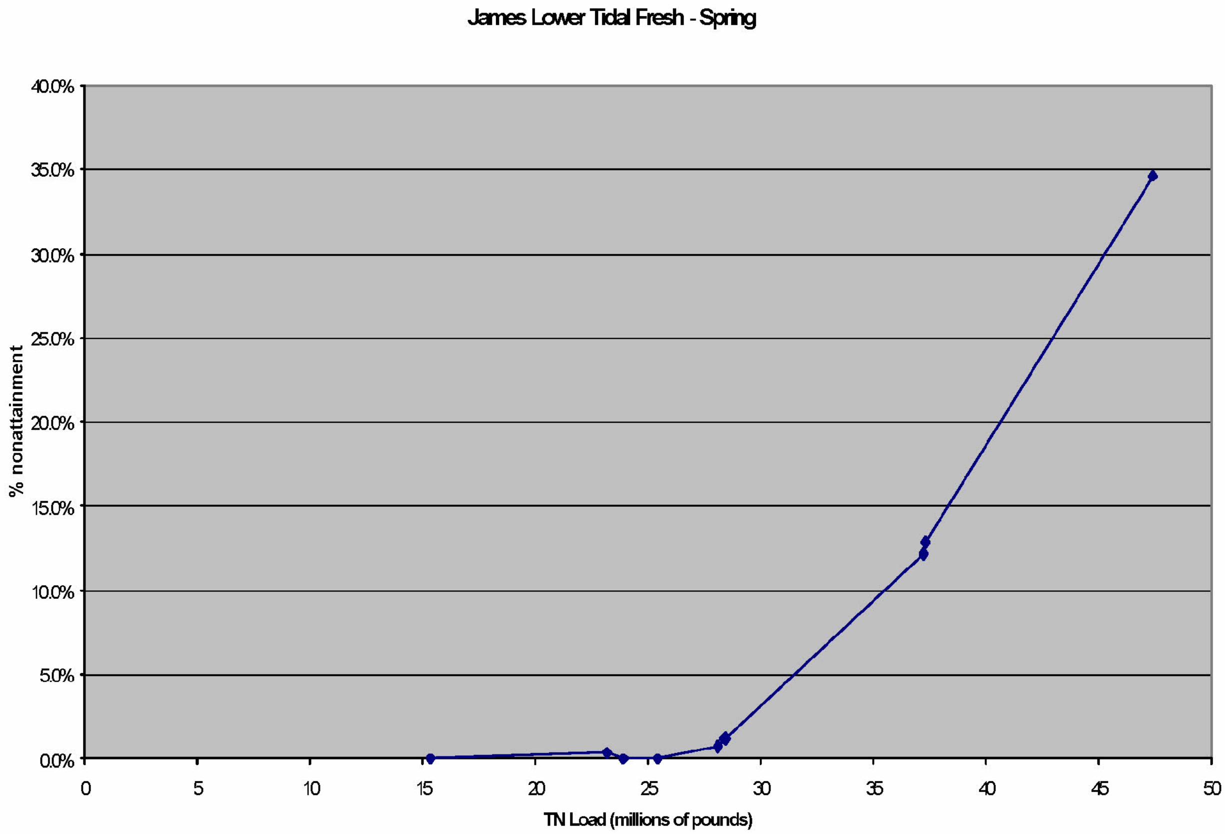
Scenario	TN Load	Percent Nonattainment
1985	46.9	3.9%
2002	37.7	3.9%
Tier 1	37.3	3.9%
Tier 2	28.2	4.0%
Option 4	28.1	4.3%
VATS	25.4	4.0%
VATS Alt.	23.9	4.0%
Tier 3	23.0	4.0%
E3	15.2	A

Figure C.2. Ten-year average Total nitrogen (TN) load (million pounds) related to the model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Upper Tidal Fresh (JMSTF2) summer period for the management scenarios.



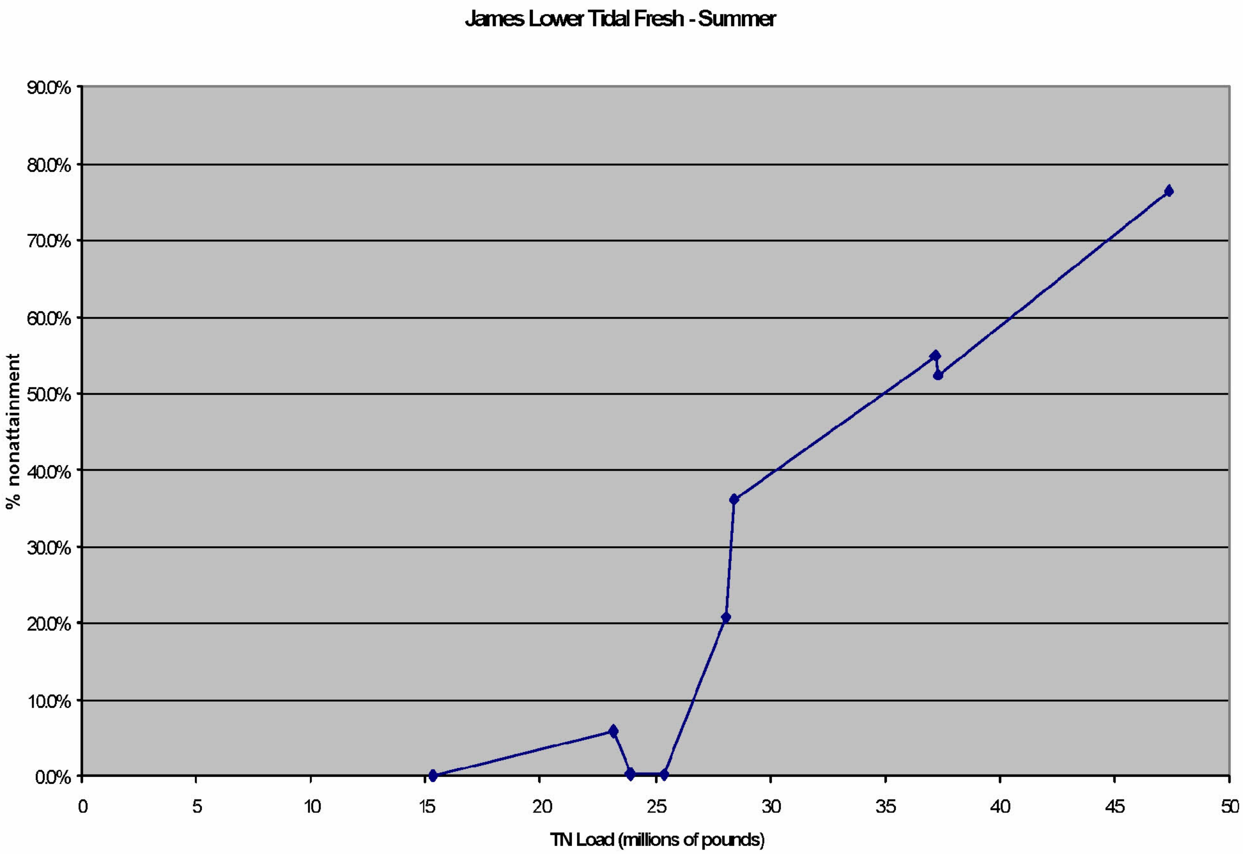
Scenario	TN Load	Percent Nonattainment
1985	46.9	0.0%
2002	37.7	3.1%
Tier 1	37.3	2.8%
Tier 2	28.2	4.6%
Option 4	28.1	6.5%
VATS	25.4	3.3%
VATS Alt.	23.9	3.3%
Tier 3	23.0	3.9%
E3	15.2	0.0%

Figure C.3. Ten-year average Total nitrogen (TN) load (million pounds) related to the model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Lower Tidal Fresh (JMSTF1) spring period for the management scenarios.



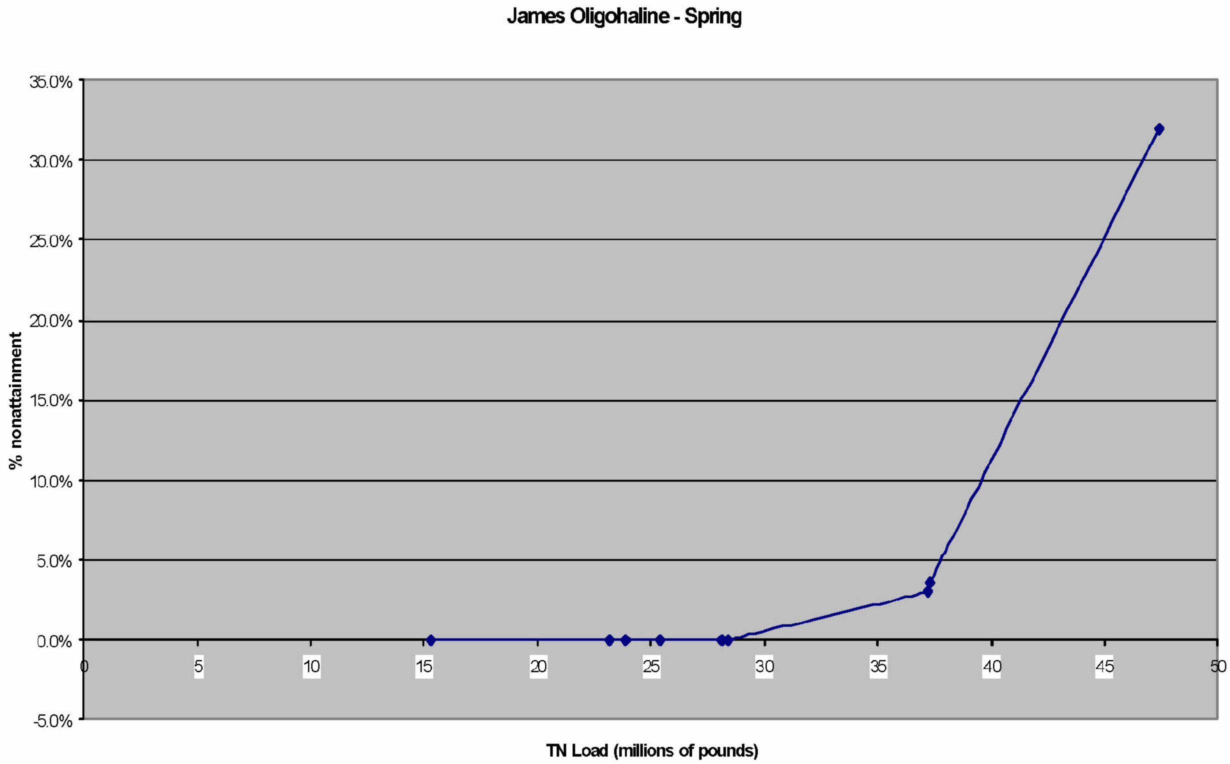
Scenario	TN Load	Percent Nonattainment
1985	46.9	34.6%
2002	37.7	12.9%
Tier 1	37.3	12.2%
Tier 2	28.2	1.2%
Option 4	28.1	0.7%
VATS	25.4	A
VATS Alt.	23.9	A
Tier 3	23.0	0.3%
E3	15.2	A

Figure C.4. Ten-year average Total nitrogen (TN) load (million pounds) related to the model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Lower Tidal Fresh (JMSTF1) summer period for the management scenarios.



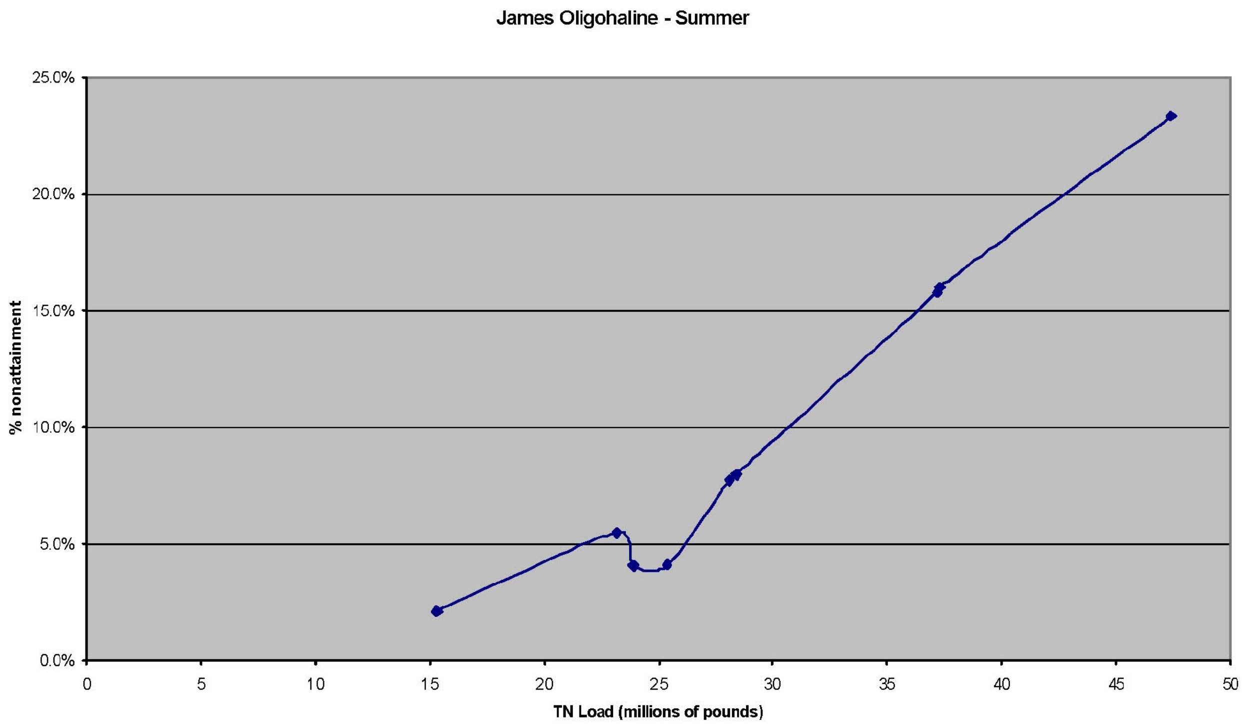
Scenario	TN Load	Percent Nonattainment
1985	46.9	76.5%
2002	37.7	52.4%
Tier 1	37.3	54.9%
Tier 2	28.2	36.1%
Option 4	28.1	20.7%
VATS	25.4	0.2%
VATS Alt.	23.9	0.2%
Tier 3	23.0	5.8%
E3	15.2	A

Figure C.5. Ten-year average Total nitrogen (TN) load (million pounds) related to the model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Oligohaline (JMSOH) spring period for the management scenarios.



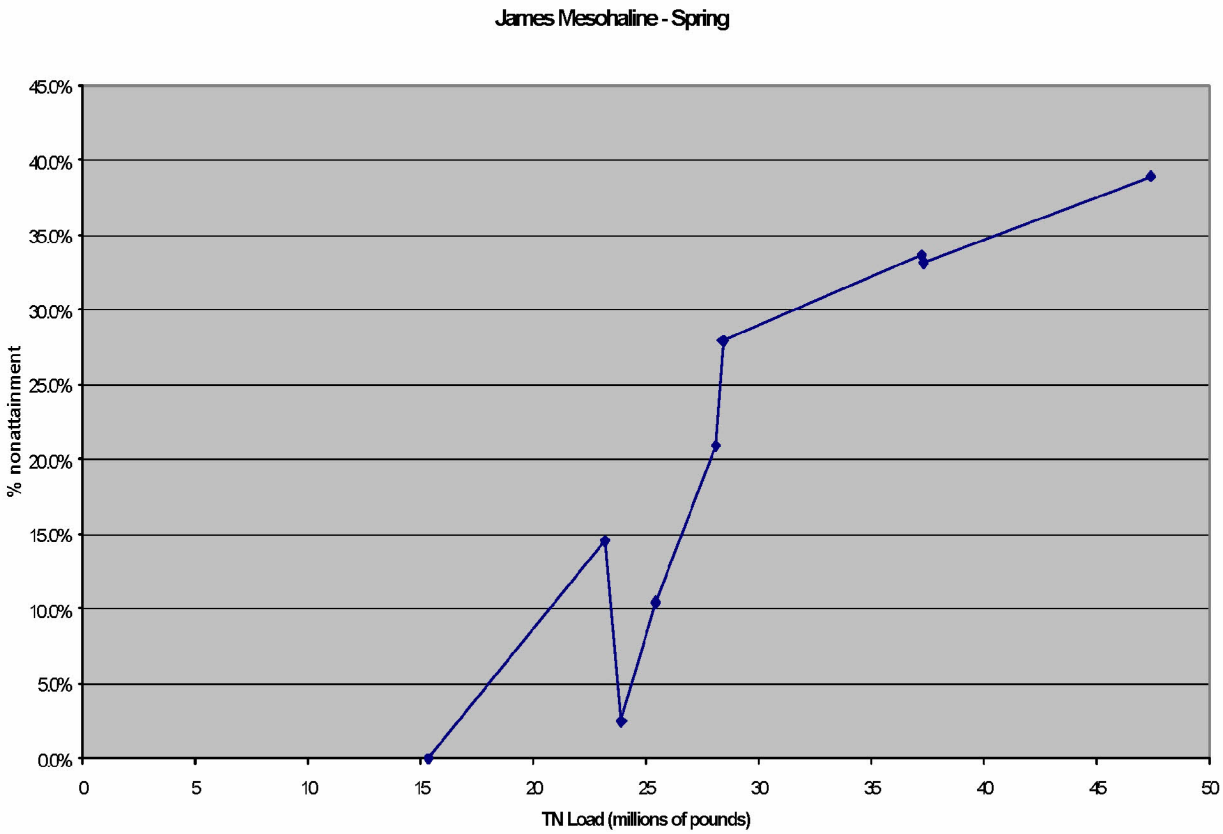
Scenario	TN Load	Percent Nonattainment
1985	46.9	31.9%
2002	37.7	3.6%
Tier 1	37.3	3.0%
Tier 2	28.2	A
Option 4	28.1	A
VATS	25.4	A
VATS Alt.	23.9	A
Tier 3	23.0	A
E3	15.2	A

Figure C.6. Ten-year average Total nitrogen (TN) load (million pounds) related to the model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Oligohaline (JMSOH) summer period for the management scenarios.



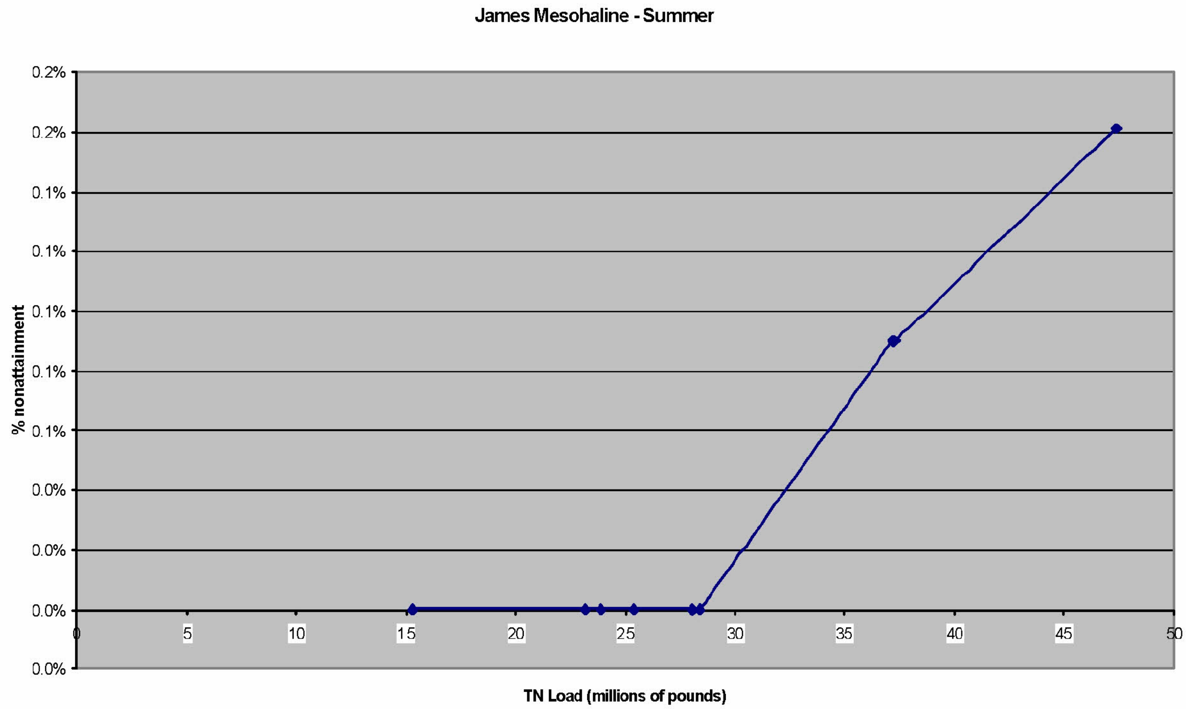
Scenario	TN Load	Percent Nonattainment
1985	46.9	23.3%
2002	37.7	16.0%
Tier 1	37.3	15.8%
Tier 2	28.2	8.0%
Option 4	28.1	7.7%
VATS	25.4	4.1%
VATS Alt.	23.9	4.0%
Tier 3	23.0	5.5%
E3	15.2	2.1%

Figure C.7. Ten-year average Total nitrogen (TN) load (million pounds) related to the model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Mesohaline (JMSMH) spring period for the management scenarios.



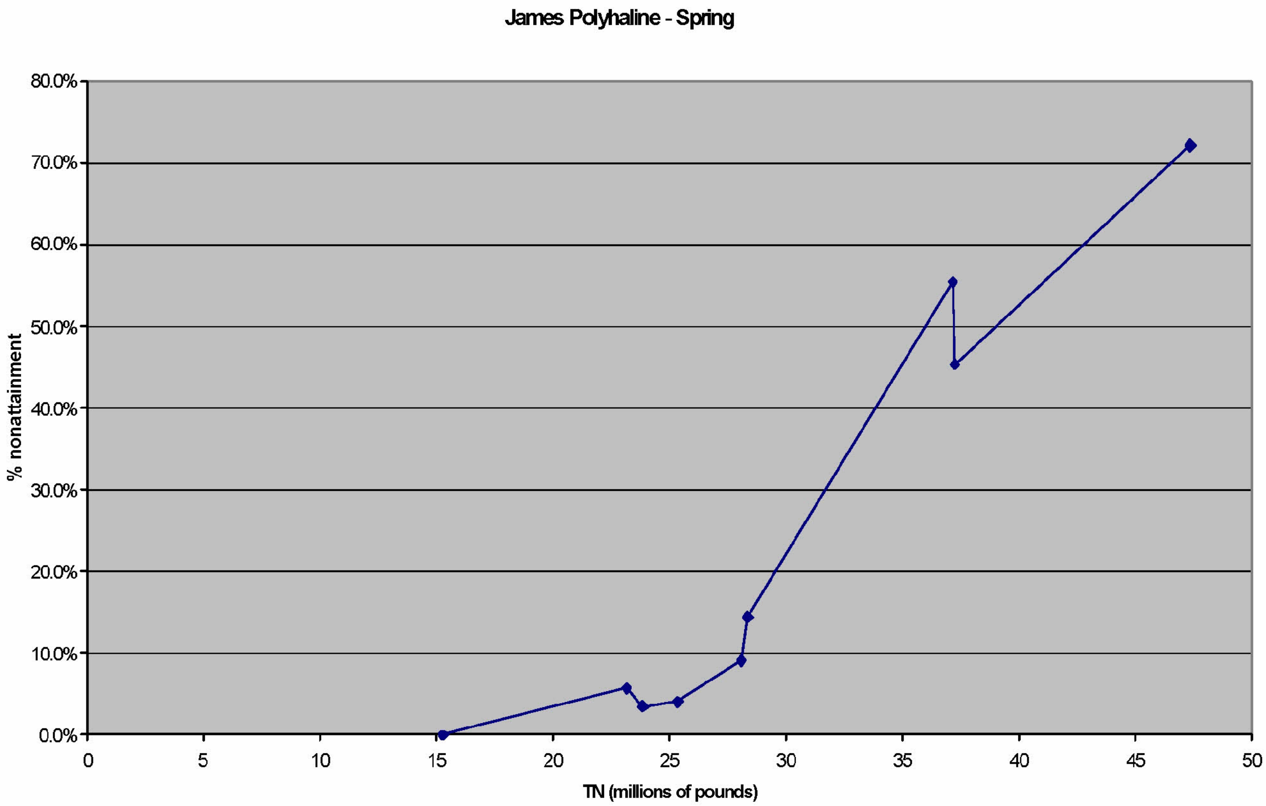
Scenario	TN Load	Percent Nonattainment
1985	46.9	38.9%
2002	37.7	33.2%
Tier 1	37.3	33.6%
Tier 2	28.2	27.9%
Option 4	28.1	20.9%
VATS	25.4	10.4%
VATS Alt.	23.9	2.5%
Tier 3	23.0	14.6%
E3	15.2	A

Figure C.8. Ten-year average Total nitrogen (TN) load (million pounds) related to the model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Mesohaline (JMSMH) summer period for the management scenarios.



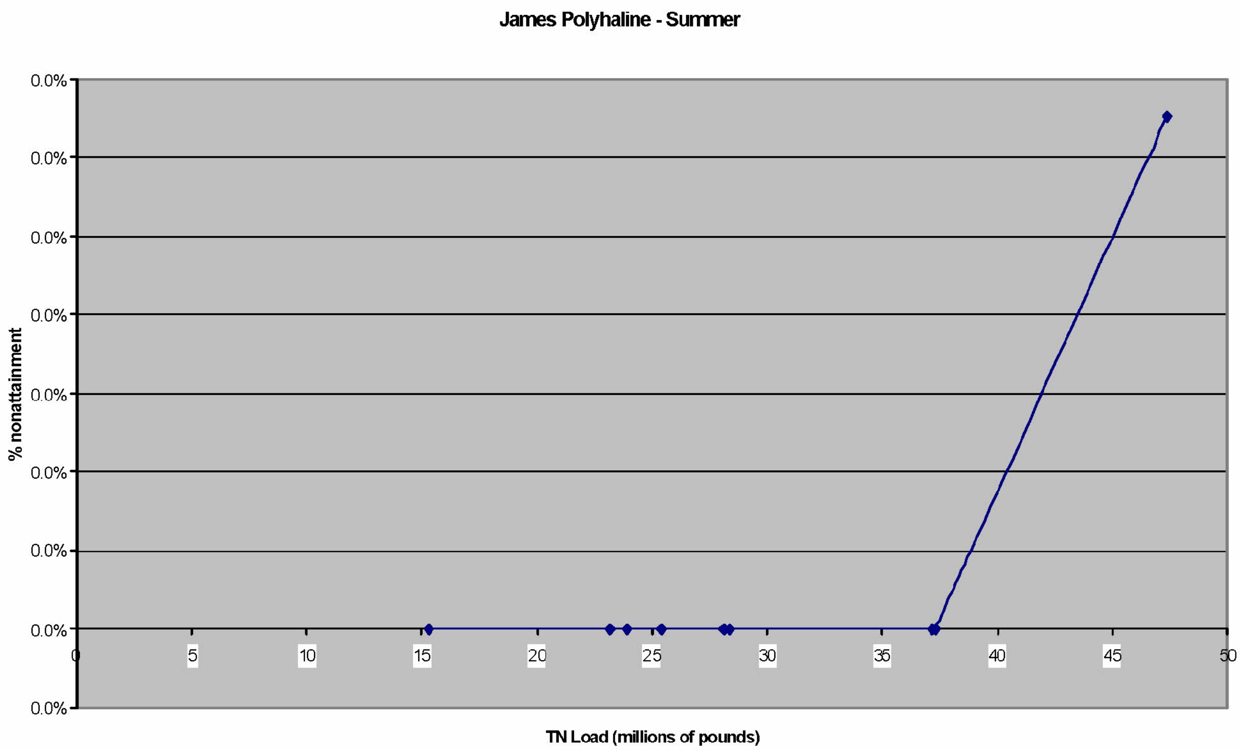
Scenario	TN Load	Percent Nonattainment
1985	46.9	0.2%
2002	37.7	0.1%
Tier 1	37.3	0.1%
Tier 2	28.2	A
Option 4	28.1	A
VATS	25.4	A
VATS Alt.	23.9	A
Tier 3	23.0	A
E3	15.2	A

Figure C.9. Ten-year average Total nitrogen (TN) load (million pounds) related to the model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Polyhaline (JMSPH) spring period for the management scenarios.



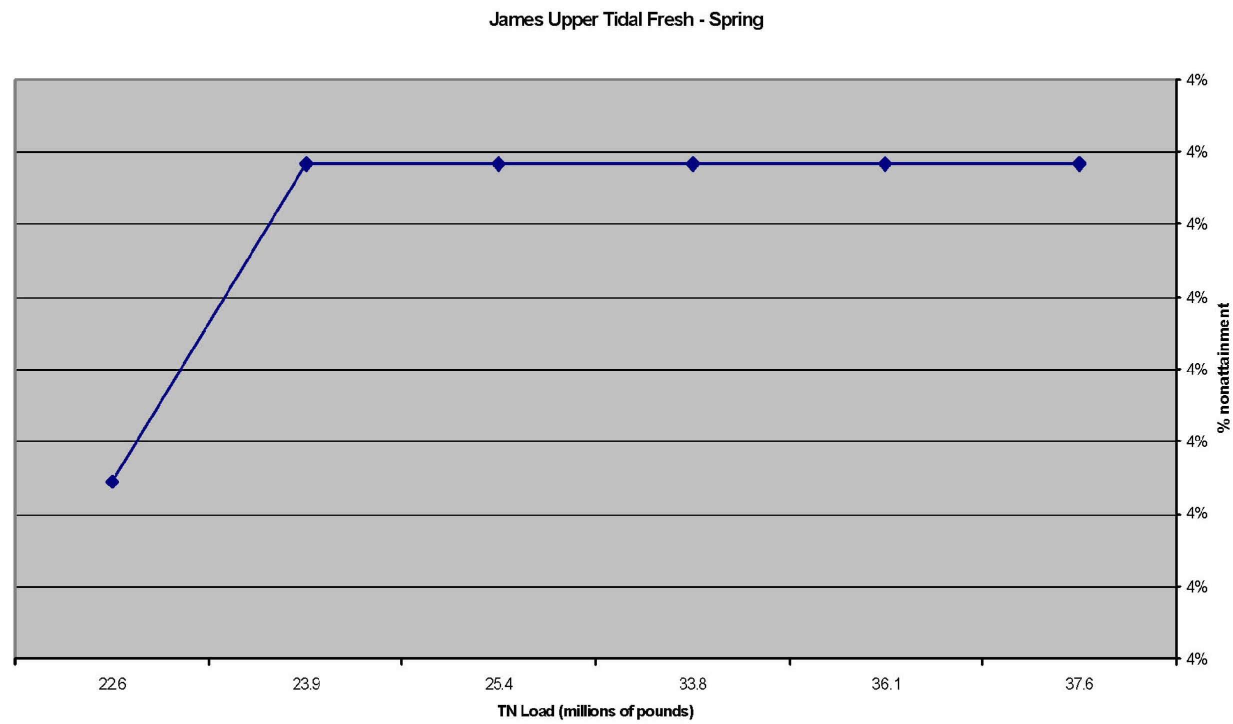
Scenario	TN Load	Percent Nonattainment
1985	46.9	72.1%
2002	37.7	45.4%
Tier 1	37.3	55.4%
Tier 2	28.2	14.4%
Option 4	28.1	9.1%
VATS	25.4	4.0%
VATS Alt.	23.9	3.5%
Tier 3	23.0	5.7%
E3	15.2	A

Figure C.10. Ten-year average Total nitrogen (TN) load (million pounds) related to the model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Polyhaline (JMSPH) summer period for the management scenarios.



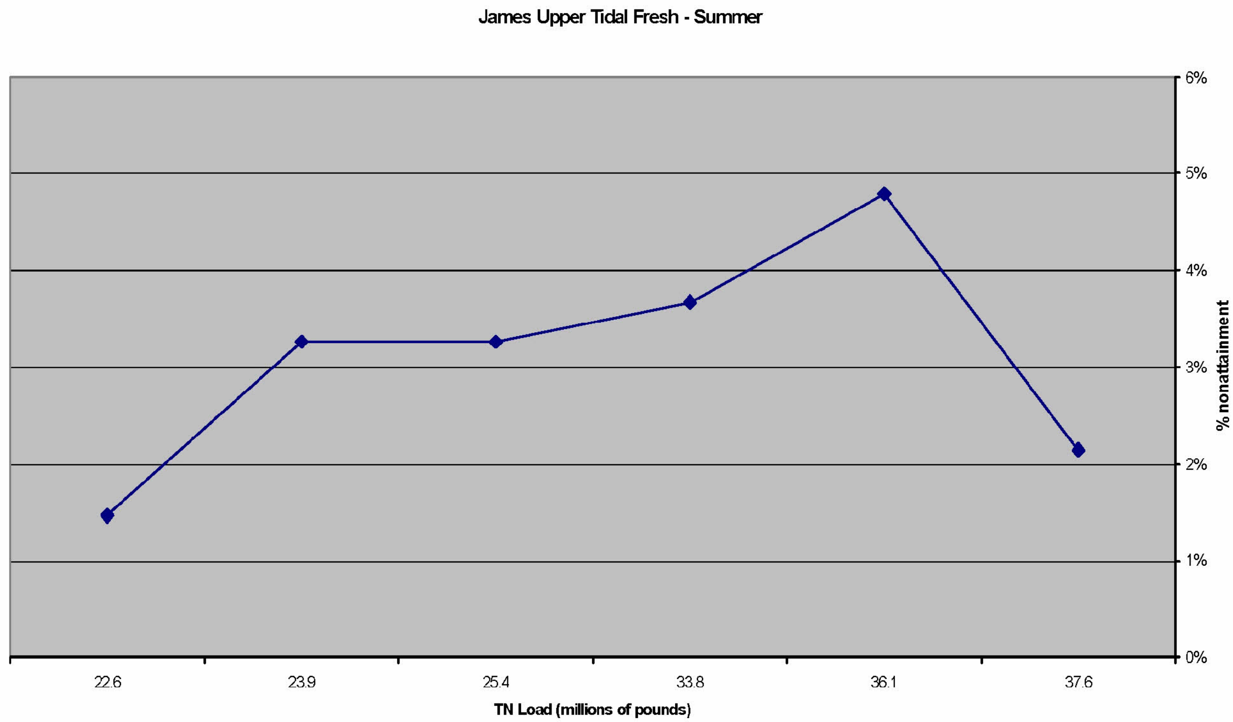
Scenario	TN Load	Percent Nonattainment
1985	46.9	0.0%
2002	37.7	A
Tier 1	37.3	A
Tier 2	28.2	A
Option 4	28.1	A
VATS	25.4	A
VATS Alt.	23.9	A
Tier 3	23.0	A
E3	15.2	A

Figure C.11. Ten-year average total nitrogen (TN) load (million pounds) related to model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Upper Tidal Fresh spring period for the scoping scenarios.



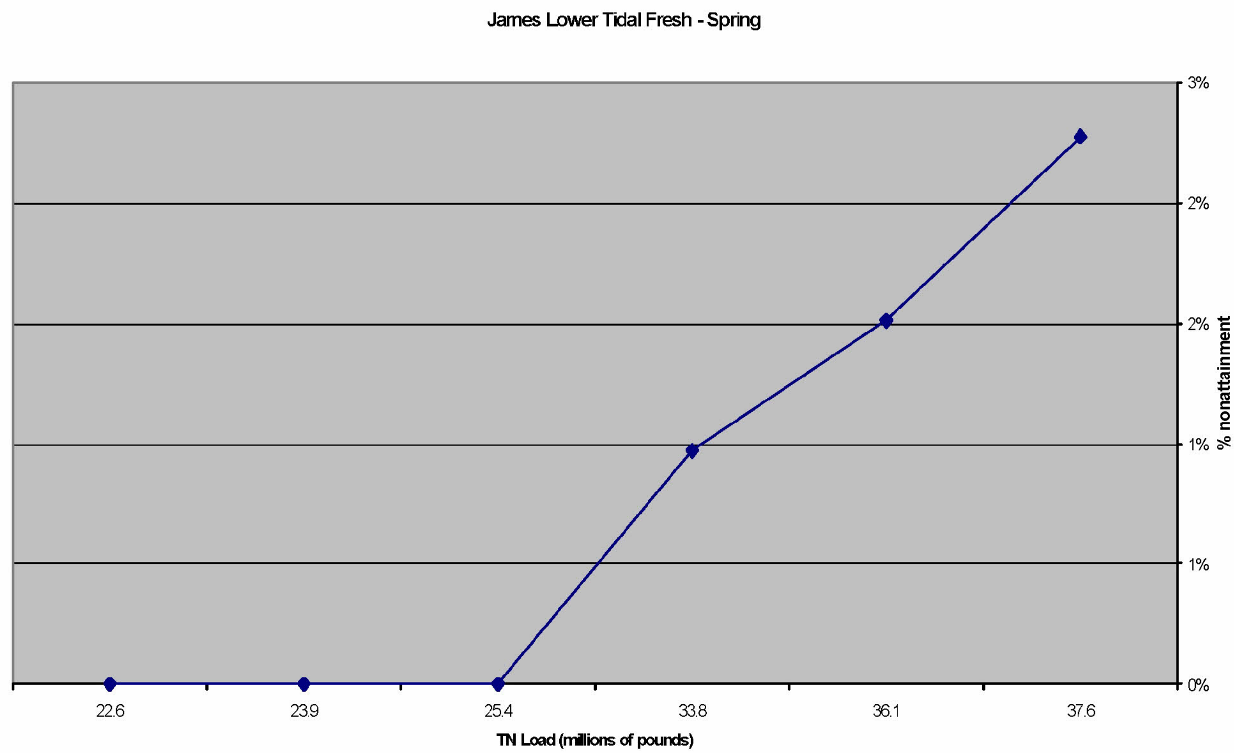
Scenario	TN Load	Percent Nonattainment
Scoping A	37.6	3.9%
Scoping C	36.1	4.0%
Scoping B	33.8	4.0%
VATS	25.4	4.0%
VATS Alt.	23.9	4.0%
Scoping D	22.6	4.0%

Figure C.12. Ten-year average total nitrogen (TN) load (million pounds) related to model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Upper Tidal Fresh summer period for the scoping scenarios.



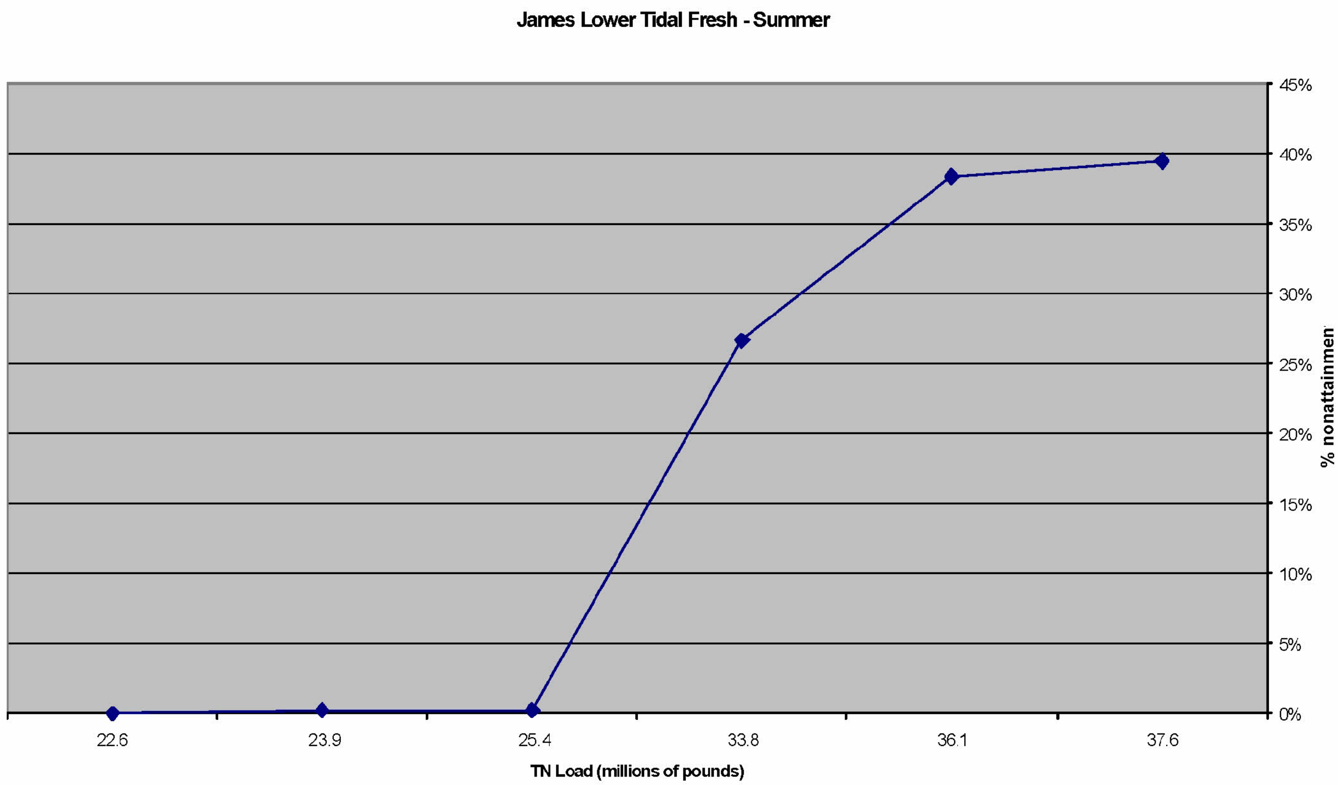
Scenario	TN Load	Percent Nonattainment
Scoping A	37.6	2.1%
Scoping C	36.1	4.8%
Scoping B	33.8	3.7%
VATS	25.4	3.3%
VATS Alt.	23.9	3.3%
Scoping D	22.6	1.5%

Figure C.13. Ten-year average total nitrogen (TN) load (million pounds) related to model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Lower Tidal Fresh spring period for the scoping scenarios.



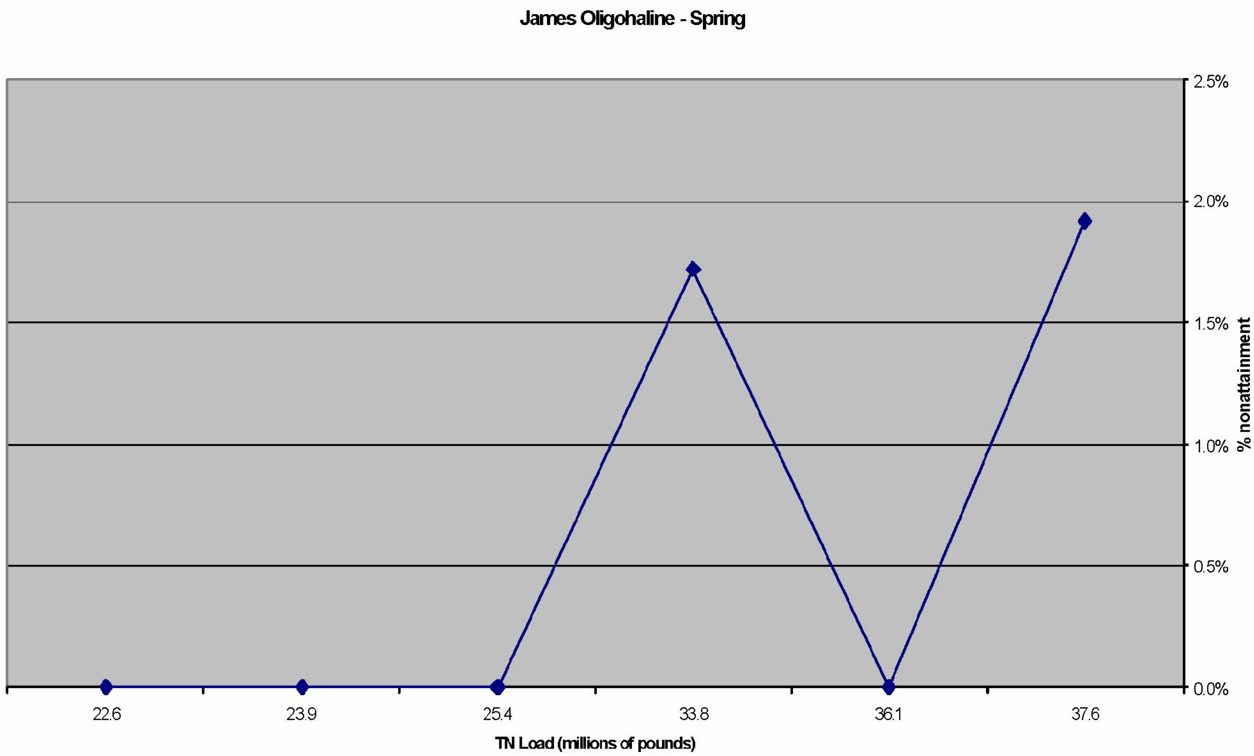
Scenario	TN Load	Percent Nonattainment
Scoping A	37.6	2.3%
Scoping C	36.1	1.5%
Scoping B	33.8	1.0%
VATS	25.4	A
VATS Alt.	23.9	A
Scoping D	22.6	A

Figure C.14. Ten-year average total nitrogen (TN) load (million pounds) related to model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Lower Tidal Fresh summer period for the scoping scenarios.



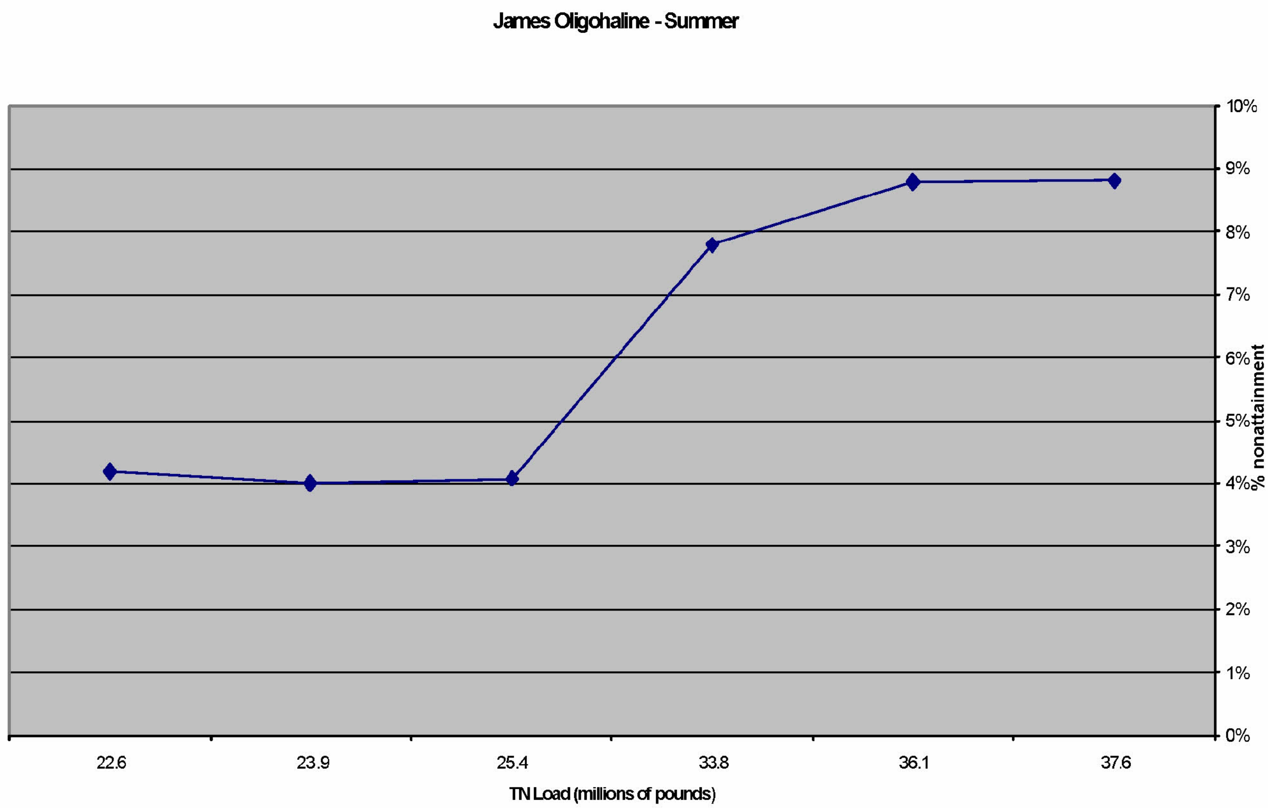
Scenario	TN Load	Percent Nonattainment
Scoping A	37.6	39.5%
Scoping C	36.1	38.3%
Scoping B	33.8	26.6%
VATS	25.4	0.2%
VATS Alt.	23.9	0.2%
Scoping D	22.6	A

Figure C.15. Ten-year average total nitrogen (TN) load (million pounds) related to model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Oligohaline spring period for the scoping scenarios.



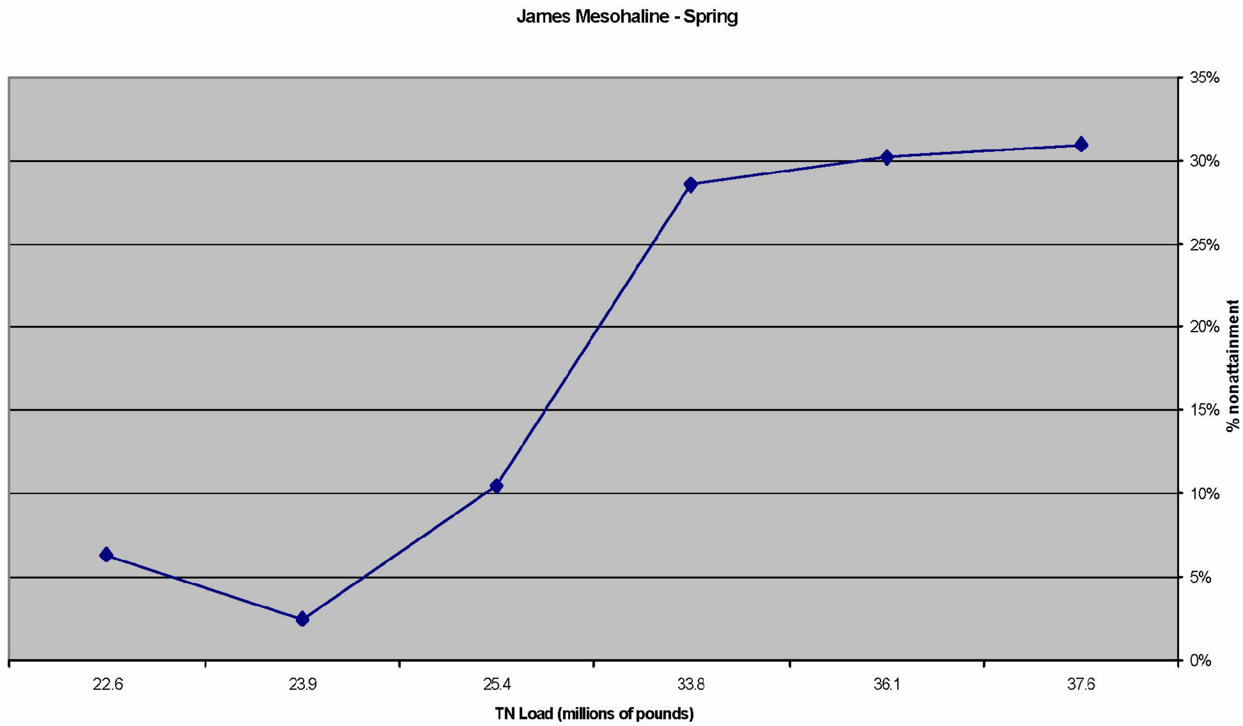
Scenario	TN Load	Percent Nonattainment
Scoping A	37.6	1.9%
Scoping C	36.1	A
Scoping B	33.8	1.7%
VATS	25.4	A
VATS Alt.	23.9	A
Scoping D	22.6	A

Figure C.16. Ten-year average total nitrogen (TN) load (million pounds) related to model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Oligohaline summer period for the scoping scenarios.



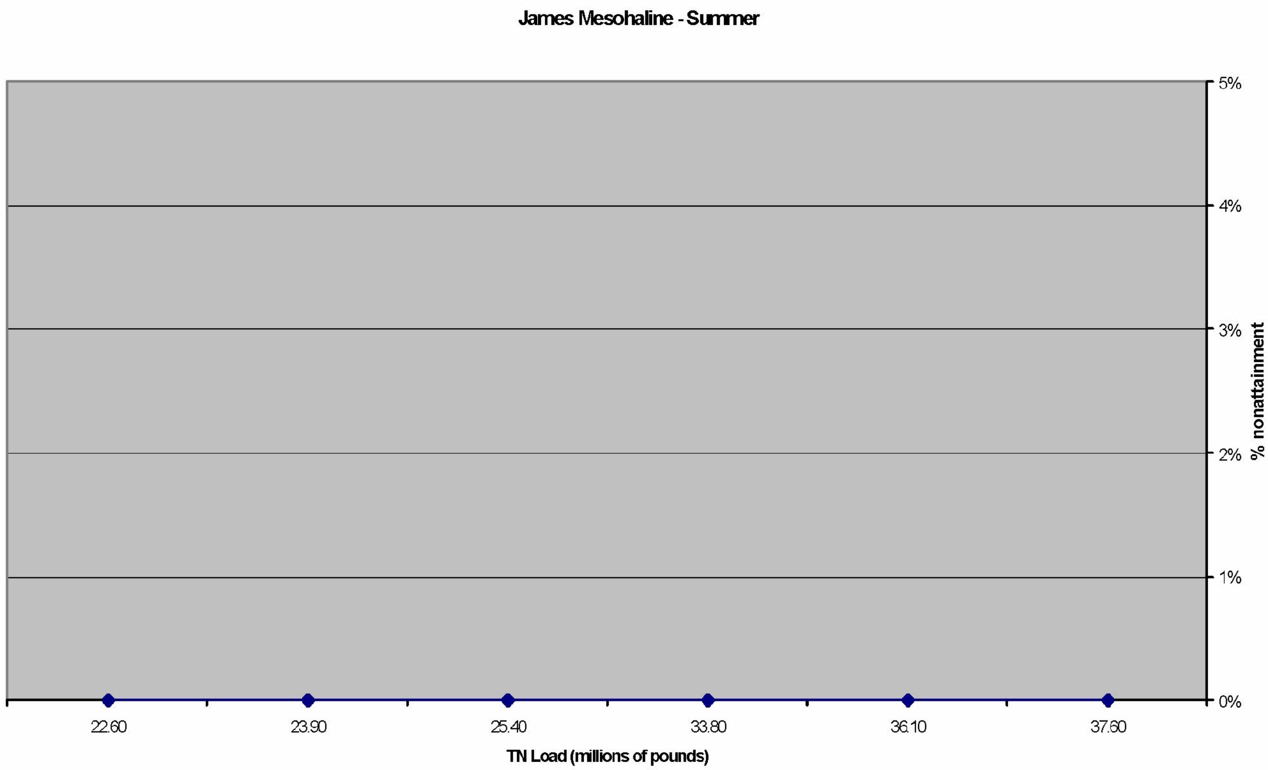
Scenario	TN Load	Percent Nonattainment
Scoping A	37.6	8.8%
Scoping C	36.1	8.8%
Scoping B	33.8	7.8%
VATS	25.4	4.1%
VATS Alt.	23.9	4.0%
Scoping D	22.6	4.2%

Figure C.17. Ten-year average total nitrogen (TN) load (million pounds) related to model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Mesohaline spring period for the scoping scenarios.



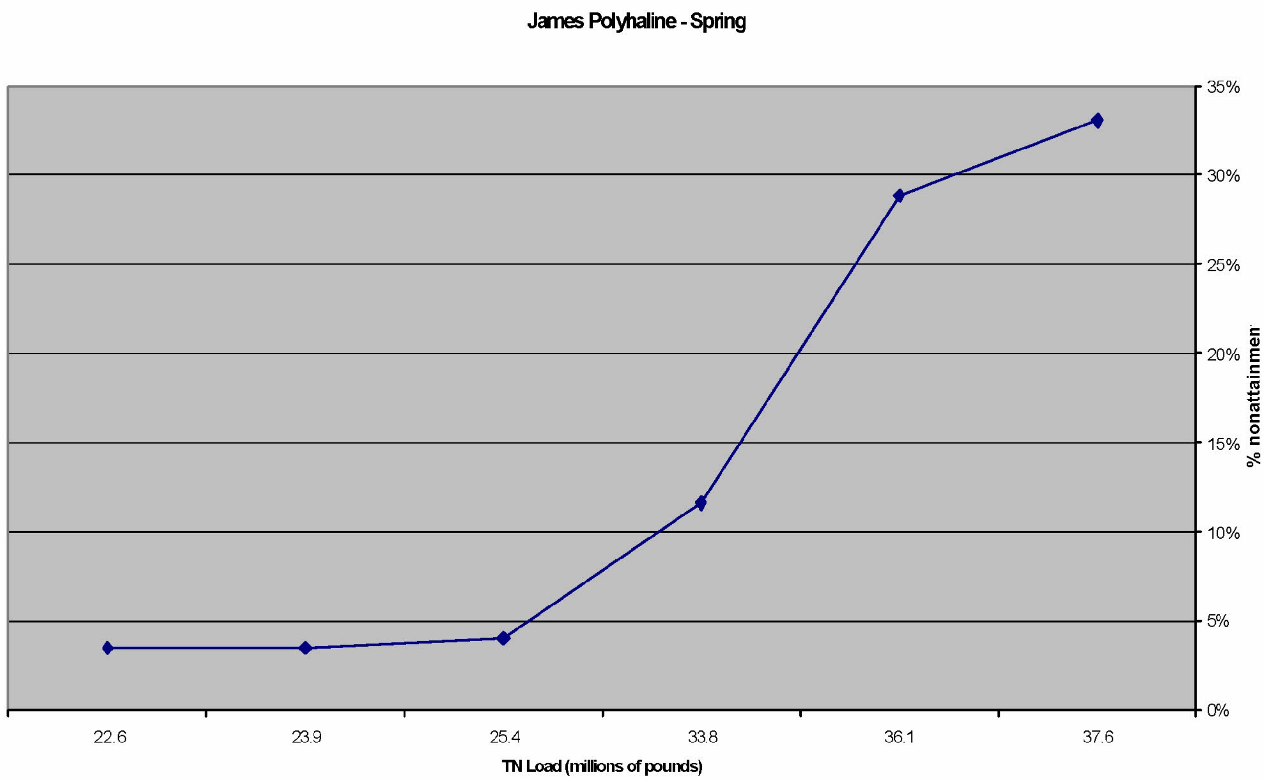
Scenario	TN Load	Percent Nonattainment
Scoping A	37.6	31.0%
Scoping C	36.1	30.2%
Scoping B	33.8	28.5%
VATS	25.4	10.4%
VATS Alt.	23.9	2.5%
Scoping D	22.6	6.3%

Figure C.18. Ten-year average total nitrogen (TN) load (million pounds) related to model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Mesohaline summer period for the scoping scenarios.



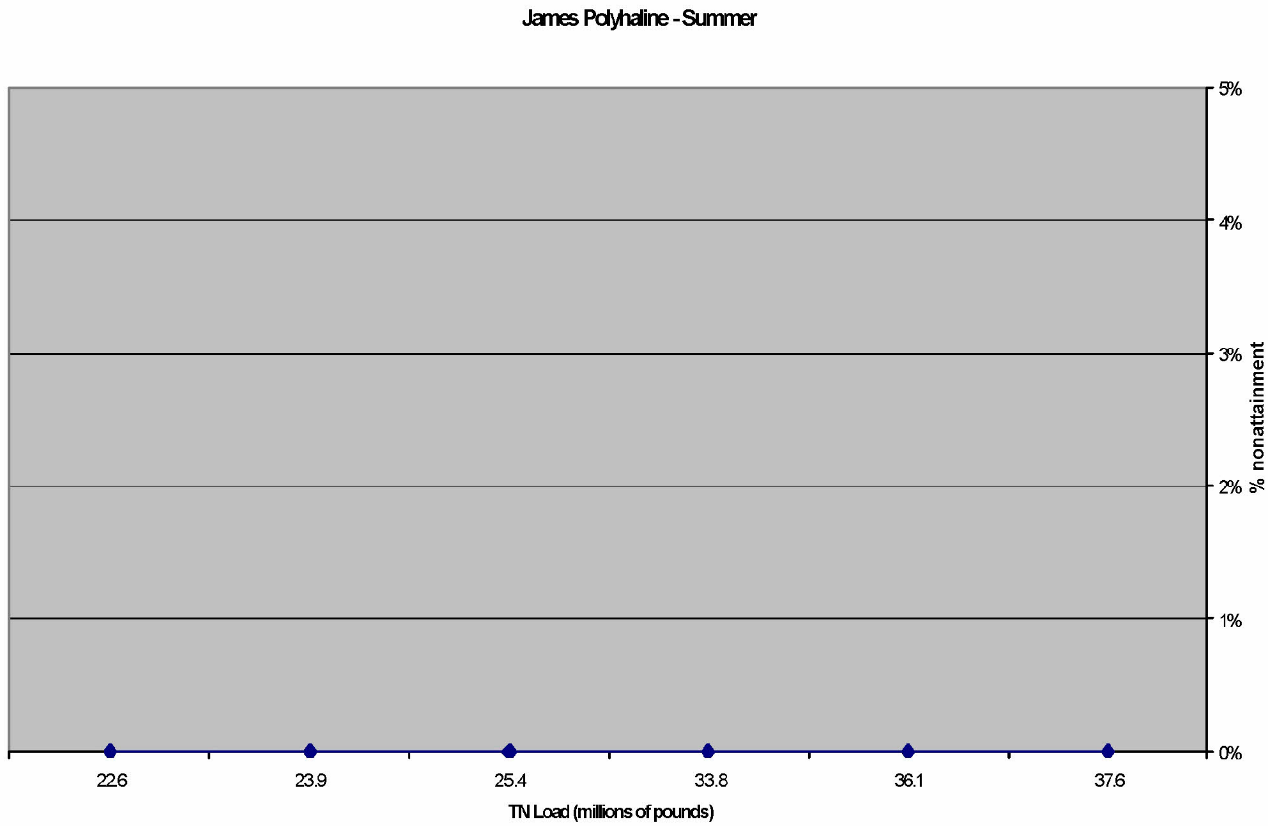
Scenario	TN Load	Percent Nonattainment
Scoping A	37.6	A
Scoping C	36.1	A
Scoping B	33.8	A
VATS	25.4	A
VATS Alt.	23.9	A
Scoping D	22.6	A

Figure C.19. Ten-year average total nitrogen (TN) load (million pounds) related to model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Polyhaline spring period for the scoping scenarios.



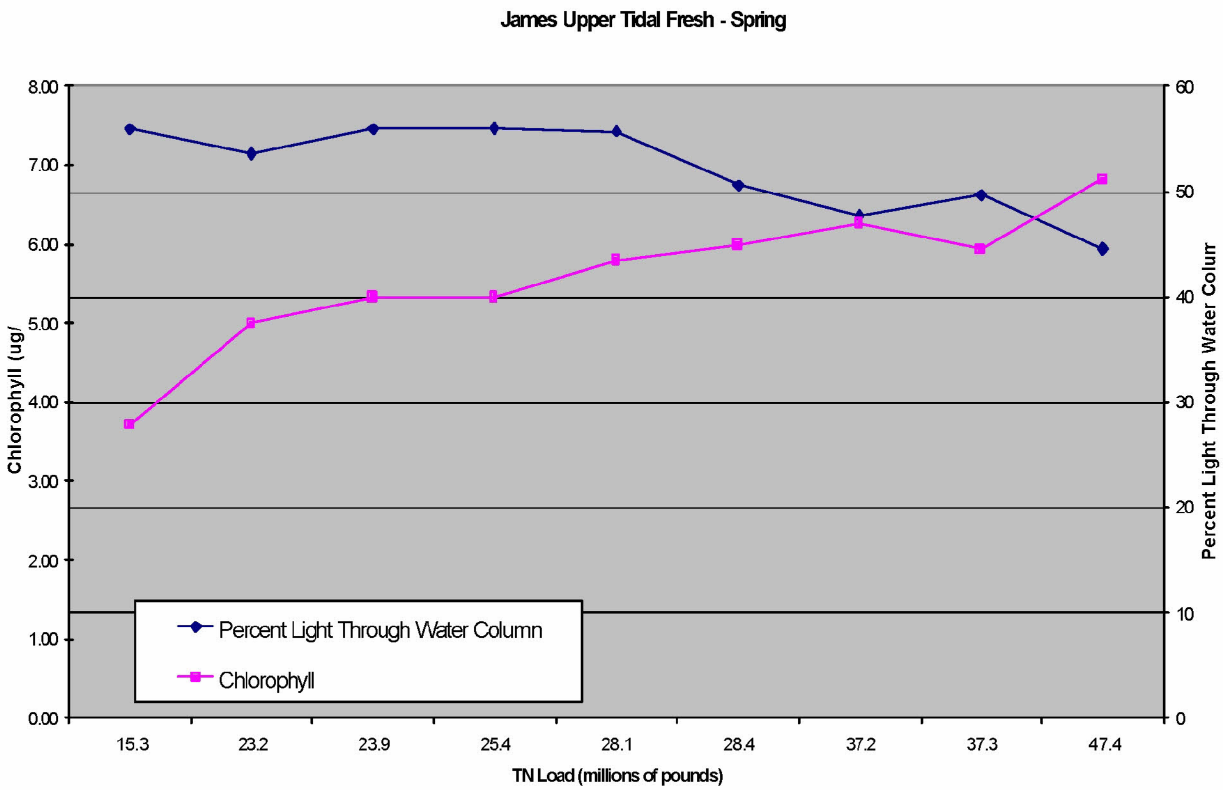
Scenario	TN Load	Percent Nonattainment
Scoping A	37.6	33.0%
Scoping C	36.1	28.8%
Scoping B	33.8	11.6%
VATS	25.4	4.0%
VATS Alt.	23.9	3.5%
Scoping D	22.6	3.5%

Figure C.20. Ten-year average total nitrogen (TN) load (million pounds) related to model simulated CFD based percent nonattainment of the proposed chlorophyll a criteria for the James Polyhaline summer period for the scoping scenarios.



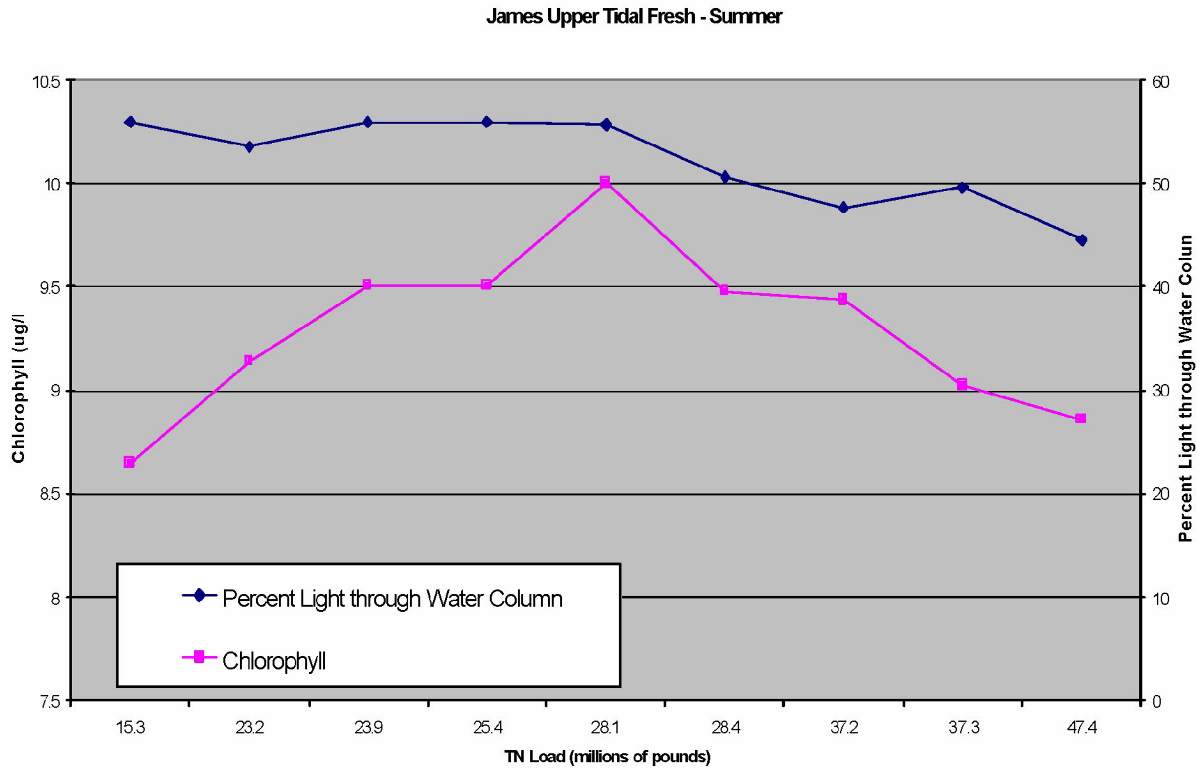
Scenario	TN Load	Percent Nonattainment
Scoping A	37.6	A
Scoping C	36.1	A
Scoping B	33.8	A
VATS	25.4	A
VATS Alt.	23.9	A
Scoping D	22.6	A

Figure C.21. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Upper Tidal Fresh spring period for the management scenarios.



Scenario	TN Load	Chlorophyll	Percent Light in Water Column
1985	46.9	6.82	44.5
2002	37.7	5.93	49.6
Tier 1	37.2	6.26	47.7
Tier 2	28.4	5.99	50.6
Option 4	28.1	5.80	55.7
VATS	25.4	5.32	56.0
VATS Alt.	23.9	5.33	55.9
Tier 3	23.0	5.00	53.6
E3	15.3	3.71	55.9

Figure C.22. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Upper Tidal Fresh summer



period for the management scenarios.

Scenario	TN Load	Chlorophyll	Percent Light in Water Column
1985	46.9	8.86	44.5
2002	37.7	9.03	49.6
Tier 1	37.3	9.44	47.7
Tier 2	28.4	9.48	50.6
Option 4	28.1	10.00	55.7
VATS	25.4	9.51	56.0
VATS Alt.	23.9	9.51	55.9
Tier 3	23.0	9.14	53.6
E3	15.2	8.65	55.9

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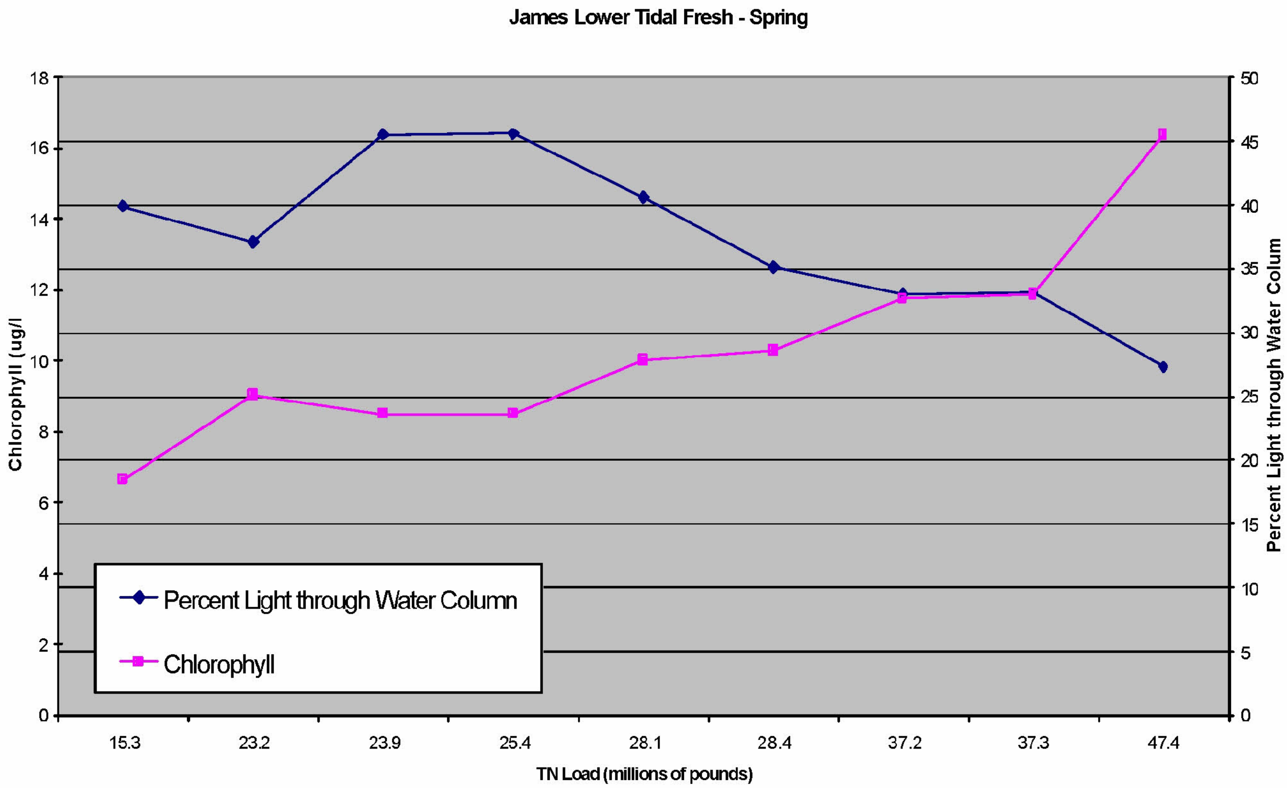
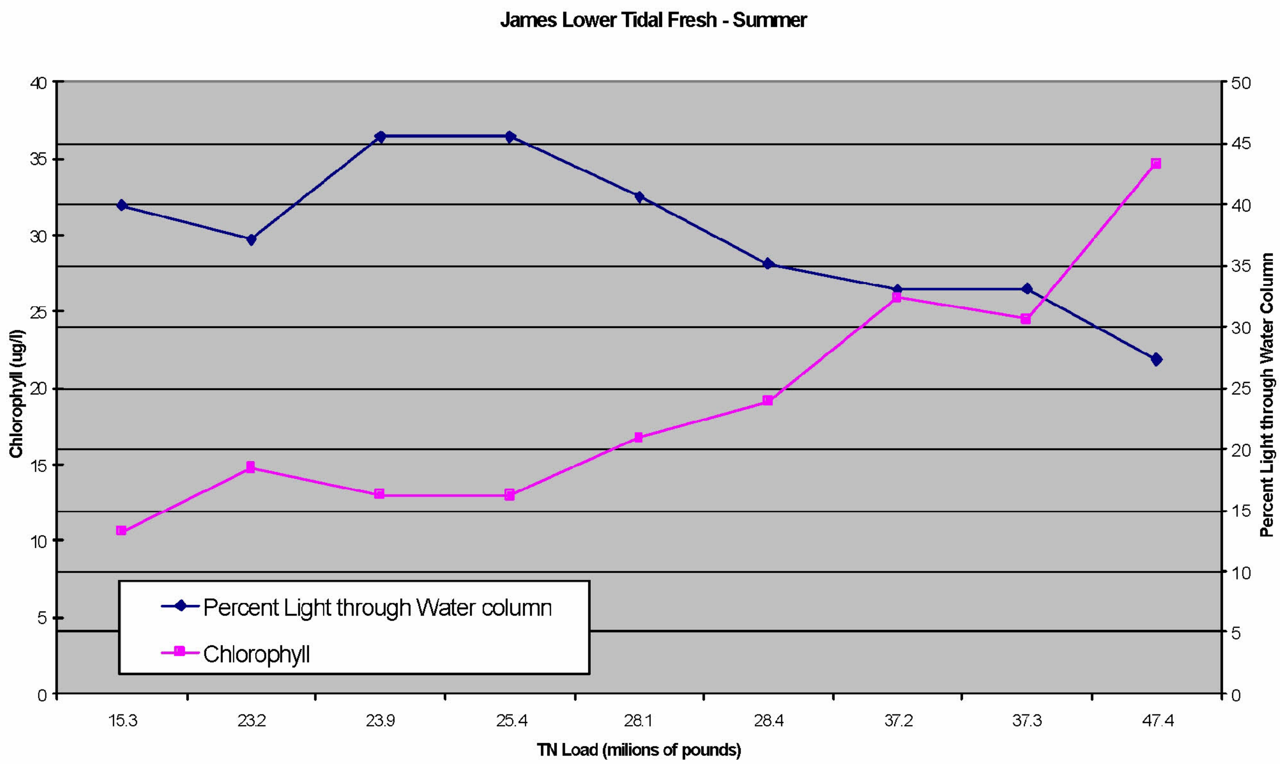
Figure C.23. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Lower Tidal Fresh spring period for the management scenarios.



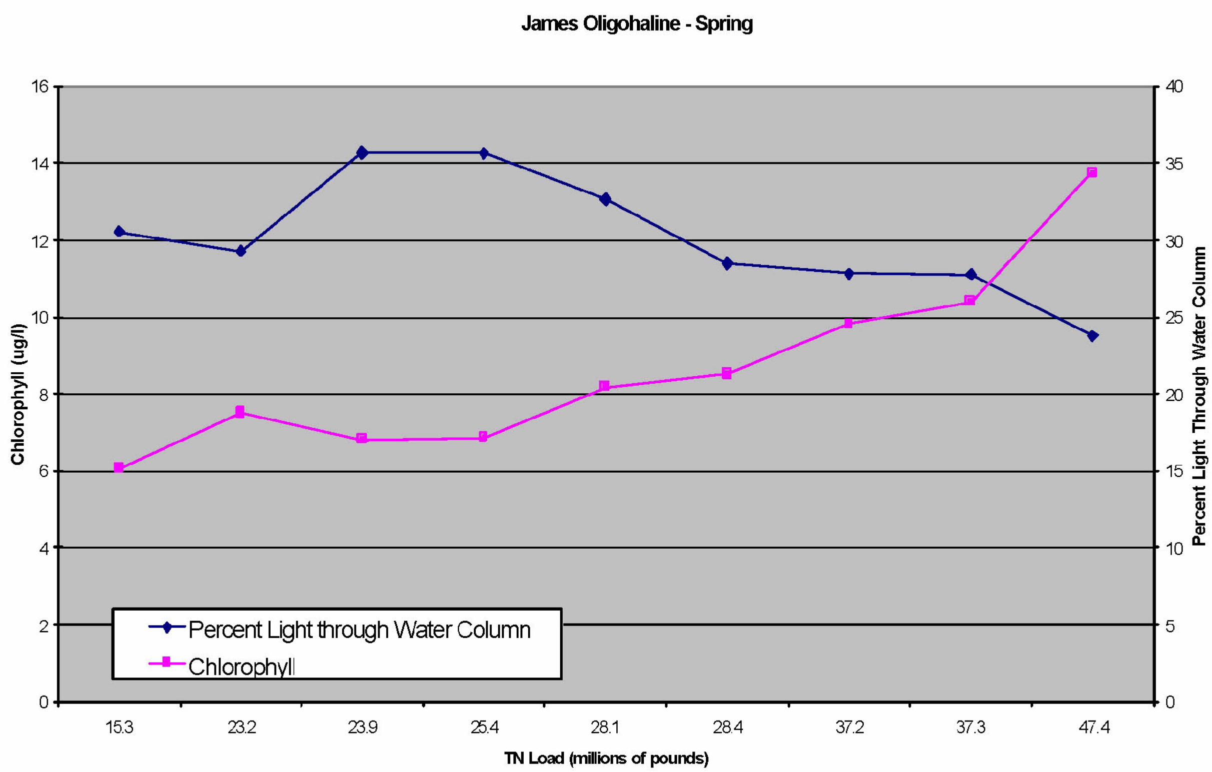
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
1985	46.9	16.37	27.3
2002	37.7	11.89	33.1
Tier 1	37.3	11.76	33.0
Tier 2	28.2	10.31	35.1
Option 4	28.1	10.02	40.6
VATS	25.4	8.50	45.6
VATS Alt.	23.9	8.51	45.6
Tier 3	23.0	9.04	37.2
E3	15.2	6.65	39.9

Figure C.24. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (μg/L) and light attenuation (percent light through water) for the James Lower Tidal Fresh summer period for the management scenarios.



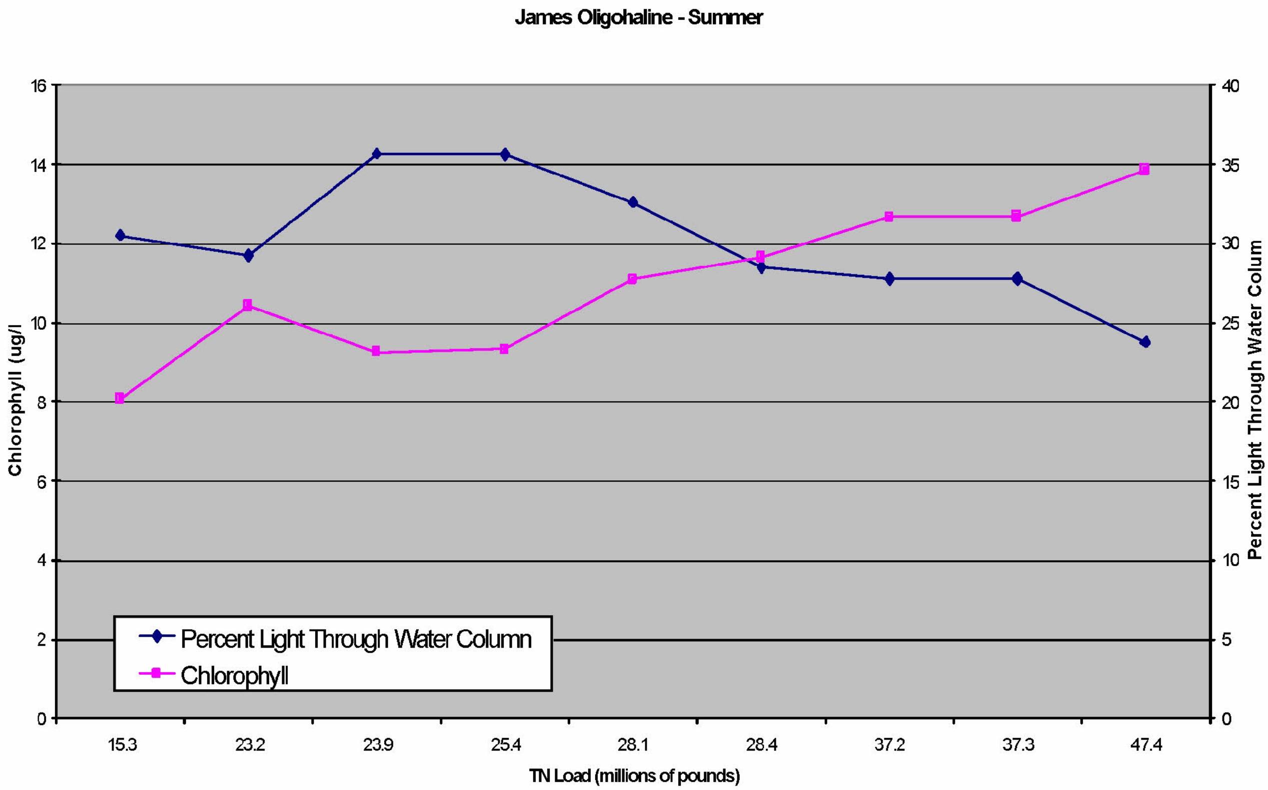
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
1985	46.9	34.66	27.3
2002	37.7	24.49	33.1
Tier 1	37.3	25.91	33.0
Tier 2	28.2	19.11	35.1
Option 4	28.1	16.74	40.6
VATS	25.4	12.97	45.6
VATS Alt.	23.9	13.01	45.6
Tier 3	23.0	14.74	37.2
E3	15.2	10.56	39.9

Figure C.25. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Oligohaline spring period for the management scenarios.



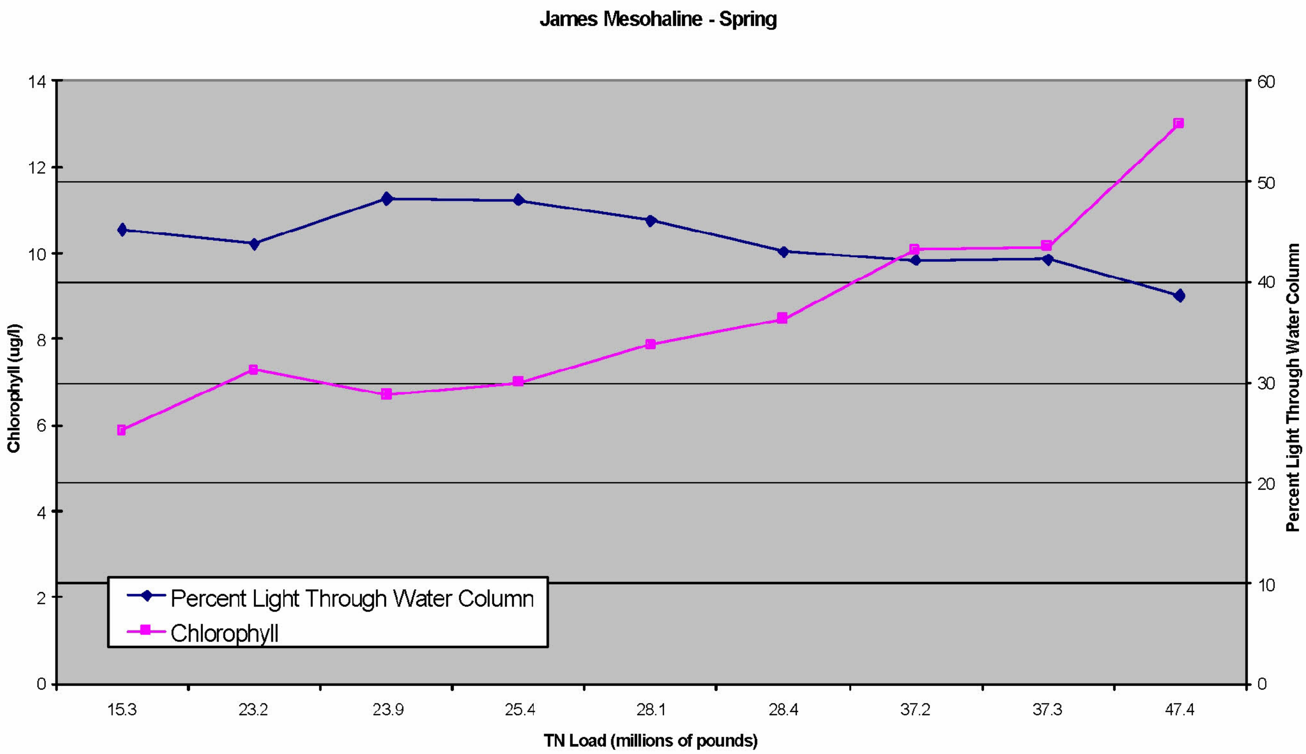
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
1985	46.9	13.74	23.8
2002	37.7	10.39	27.8
Tier 1	37.3	9.81	27.8
Tier 2	28.2	8.52	28.5
Option 4	28.1	8.17	32.6
VATS	25.4	6.88	35.6
VATS Alt.	23.9	6.81	35.7
Tier 3	23.0	7.50	29.3
E3	15.2	6.06	30.5

Figure C.26. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Oligohaline summer period for the management scenarios.



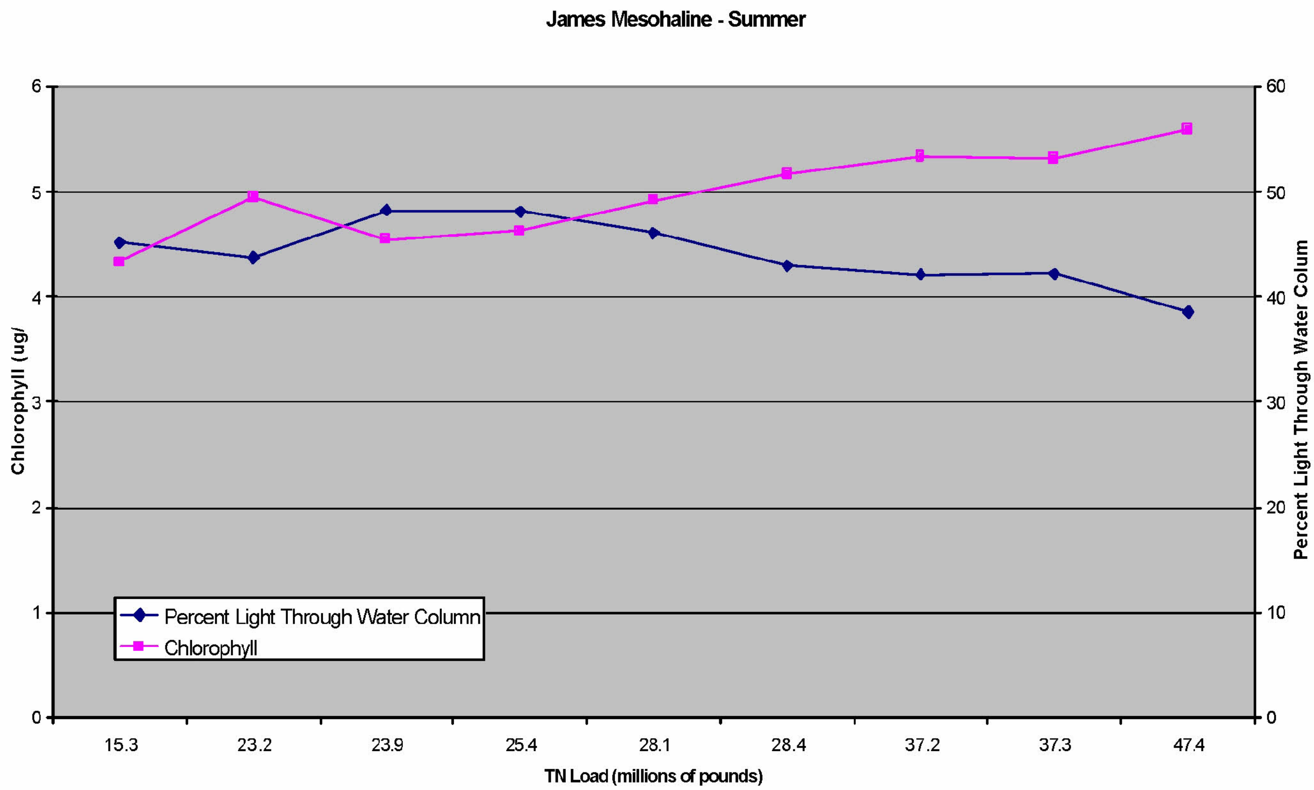
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
1985	46.9	13.85	23.8
2002	37.7	12.68	27.8
Tier 1	37.3	12.67	27.8
Tier 2	28.2	11.65	28.5
Option 4	28.1	11.10	32.6
VATS	25.4	9.32	35.6
VATS Alt.	23.9	9.27	35.7
Tier 3	23.0	10.42	29.3
E3	15.2	8.06	30.5

Figure C.27. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Mesohaline spring period for the management scenarios.



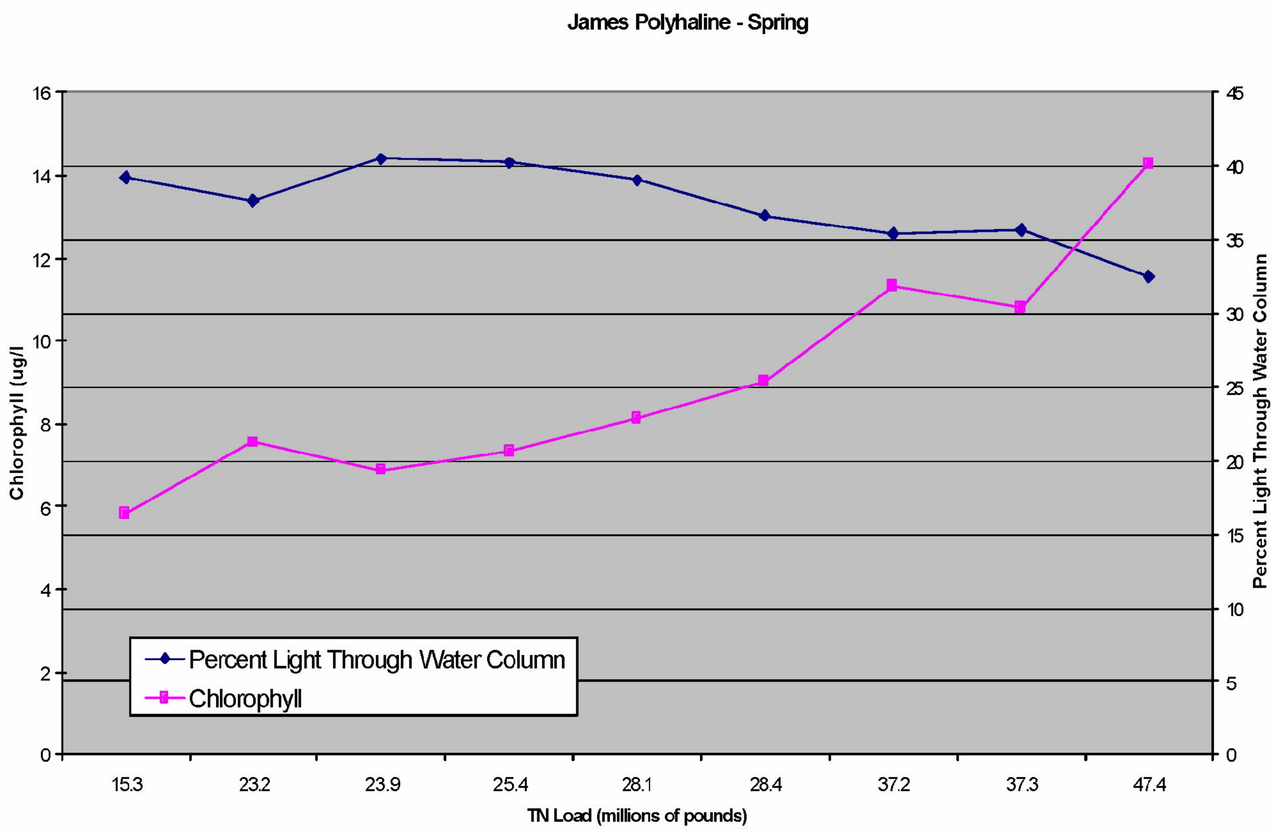
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
1985	46.9	13.00	38.6
2002	37.7	10.14	42.2
Tier 1	37.3	10.07	42.1
Tier 2	28.2	8.46	42.9
Option 4	28.1	7.87	46.0
VATS	25.4	7.00	48.1
VATS Alt.	23.9	6.71	48.2
Tier 3	23.0	7.28	43.7
E3	15.2	5.88	45.2

Figure C.28. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Mesohaline summer period for the management scenarios.



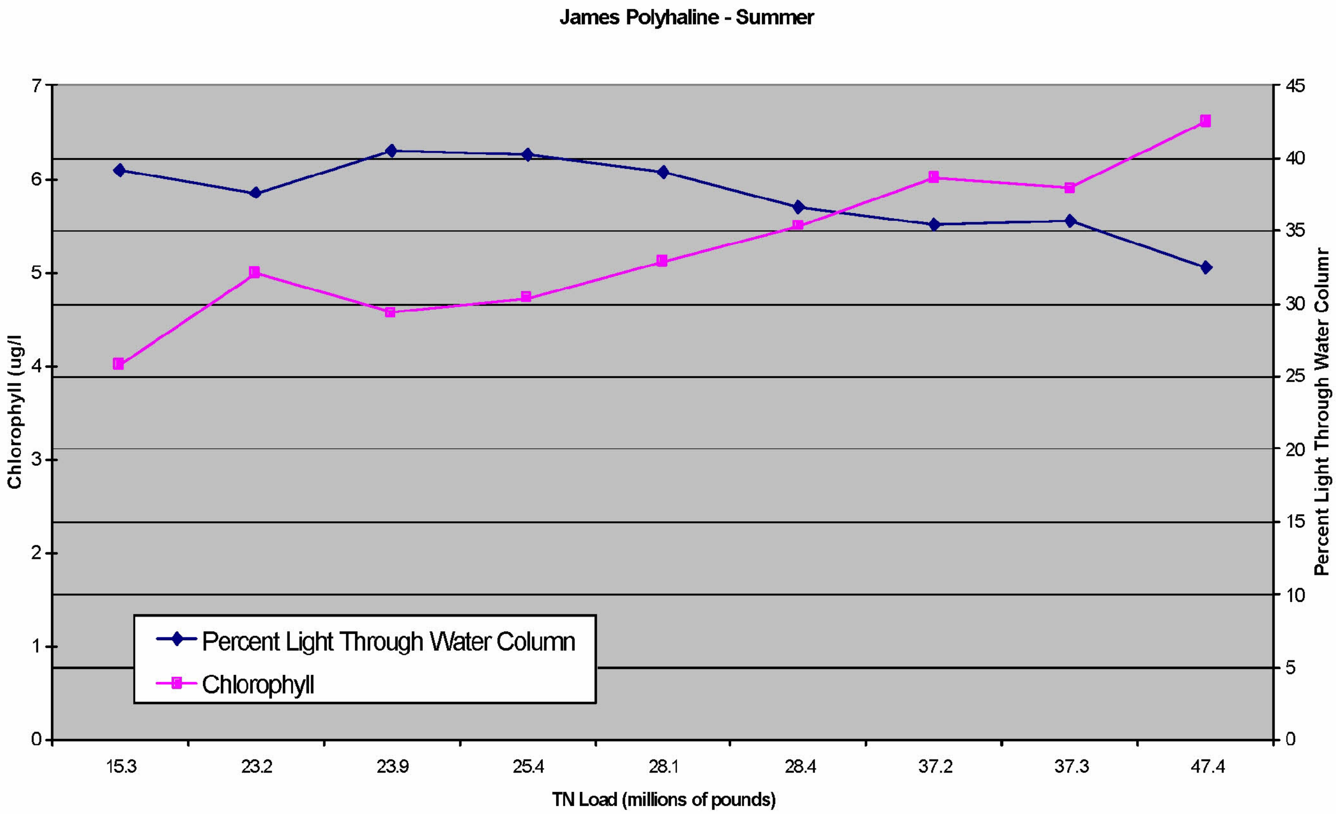
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
1985	46.9	5.59	38.6
2002	37.7	5.32	42.2
Tier 1	37.3	5.33	42.1
Tier 2	28.2	5.17	42.9
Option 4	28.1	4.92	46.0
VATS	25.4	4.62	48.1
VATS Alt.	23.9	4.55	48.2
Tier 3	23.0	4.94	43.7
E3	15.2	4.33	45.2

Figure C.29. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Polyhaline spring period for the management scenarios.



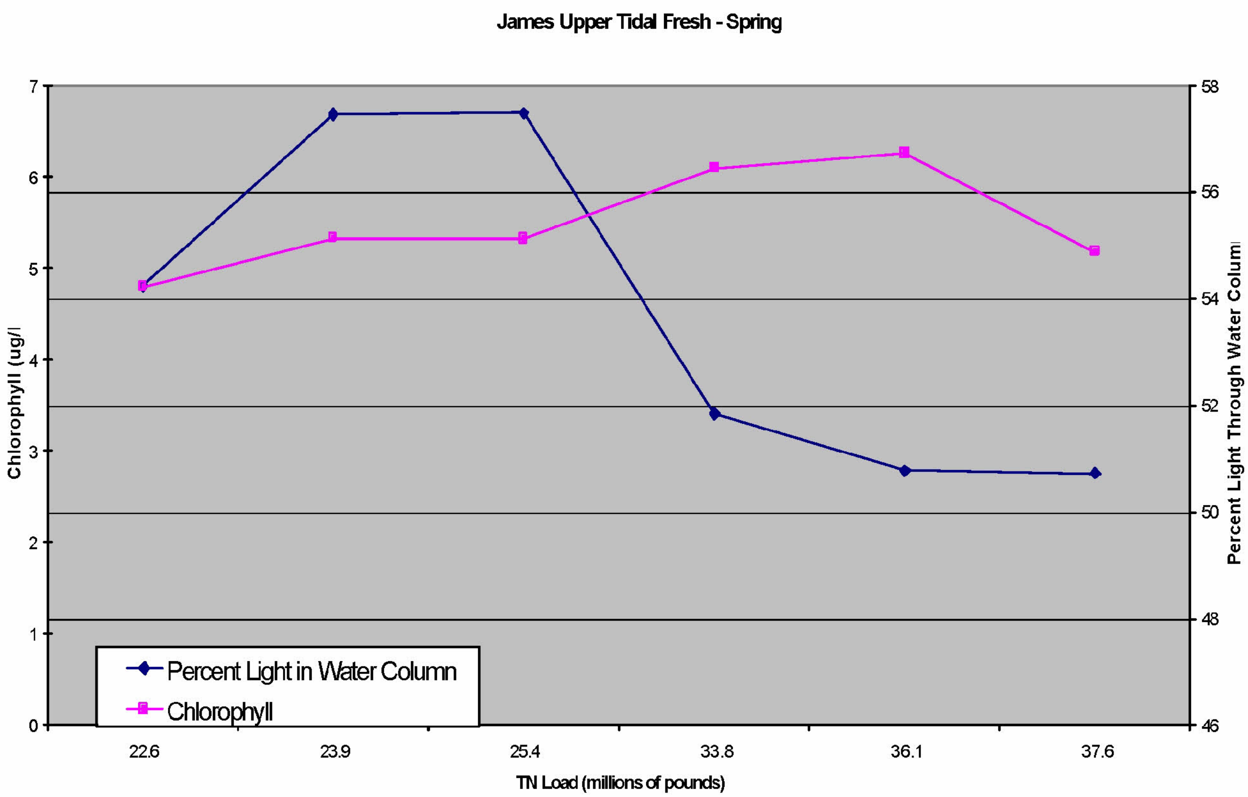
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
1985	46.9	14.26	32.5
2002	37.7	10.79	35.7
Tier 1	37.3	11.33	35.4
Tier 2	28.2	9.00	36.6
Option 4	28.1	8.13	39.0
VATS	25.4	7.34	40.2
VATS Alt.	23.9	6.88	40.5
Tier 3	23.0	7.54	37.6
E3	15.2	5.83	39.2

Figure C.30. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Polyhaline summer period for the management scenarios.



Scenario	TN Load	Chlorophyll	Percent Light in Water Column
1985	46.9	6.62	32.5
2002	37.7	5.90	35.7
Tier 1	37.3	6.01	35.4
Tier 2	28.2	5.50	36.6
Option 4	28.1	5.12	39.0
VATS	25.4	4.73	40.2
VATS Alt.	23.9	4.57	40.5
Tier 3	23.0	4.99	37.6
E3	15.2	4.01	39.2

Figure C.31. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Upper Tidal Fresh spring period for the scoping scenarios.



Scenario	TN Load	Chlorophyll	Percent Light in Water Column
Scoping A	37.6	5.19	50.7
Scoping C	36.1	6.26	50.8
Scoping B	33.8	6.10	51.8
VATS	25.4	5.32	57.5
VATS Alt.	23.9	5.33	57.5
Scoping D	22.6	4.80	54.2

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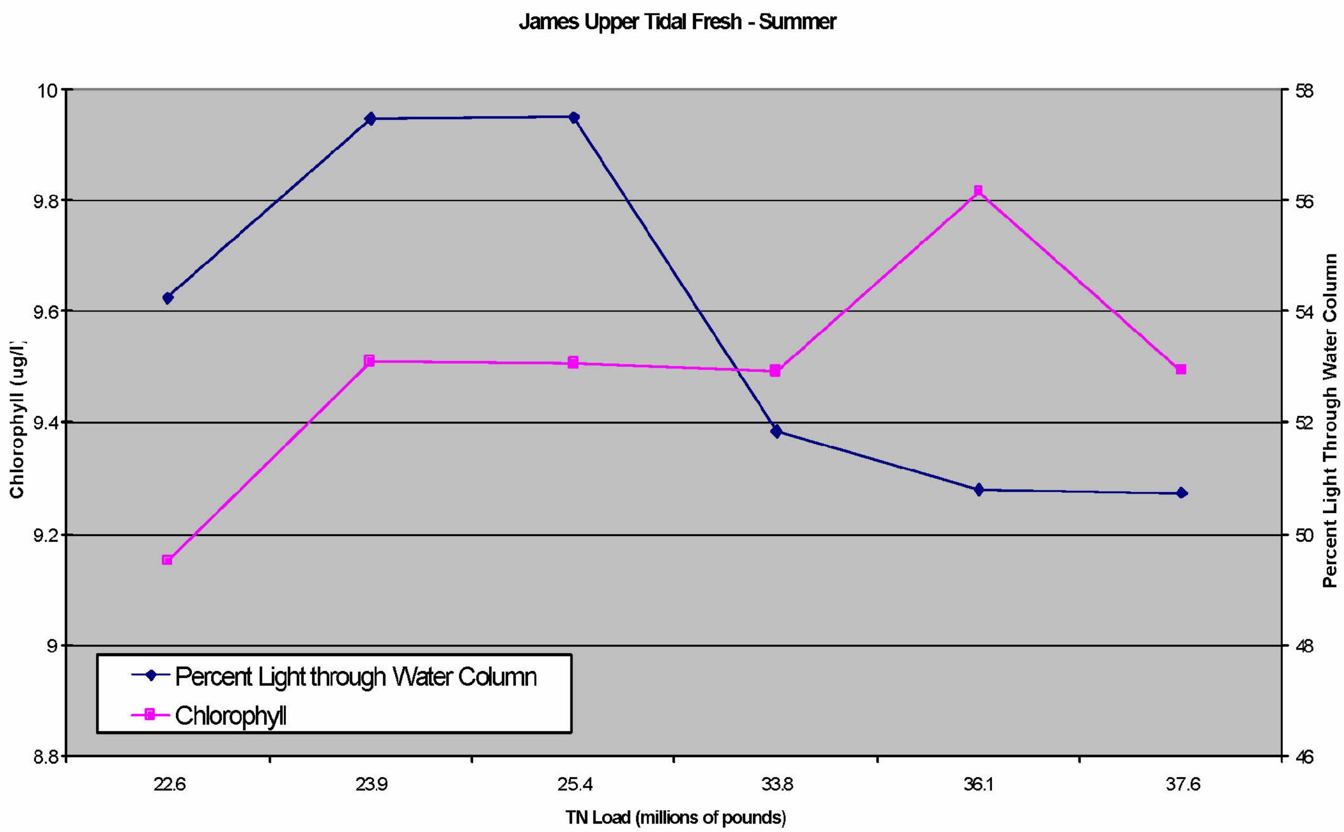
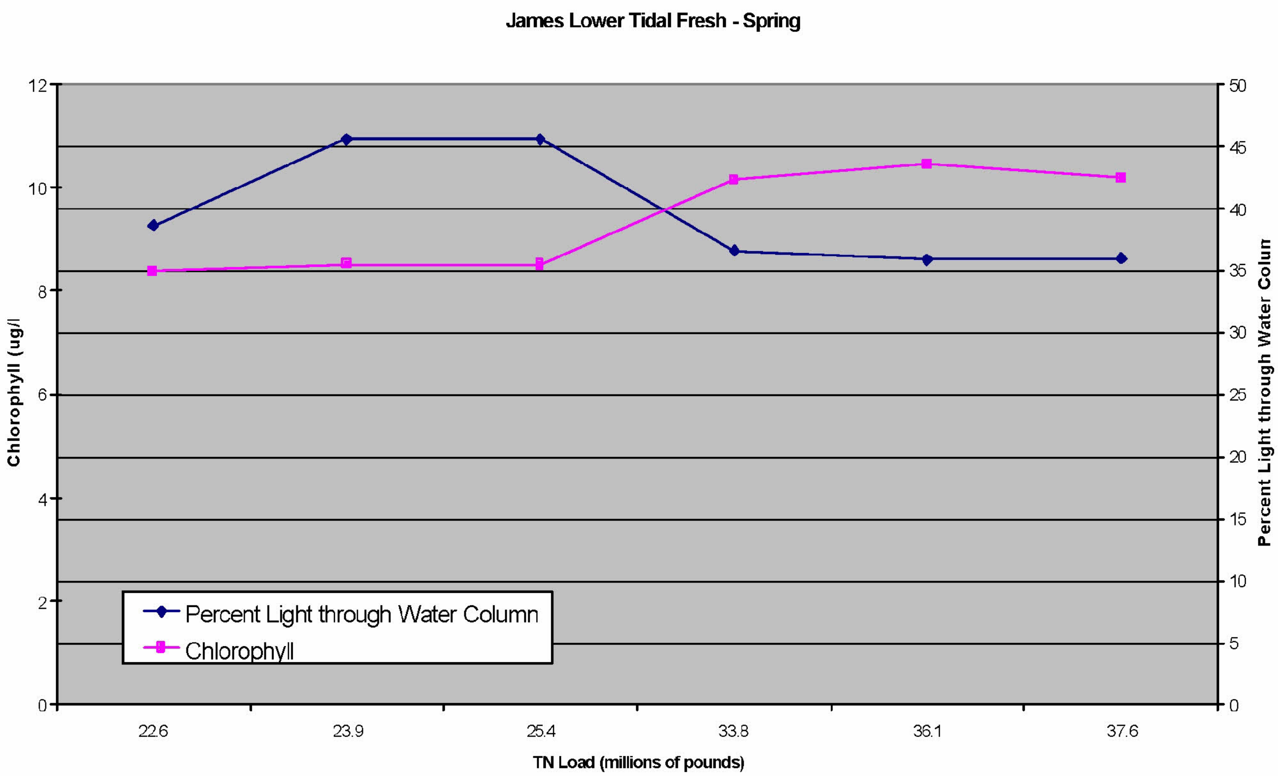
Figure C.32. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Upper Tidal Fresh summer period for the scoping scenarios.



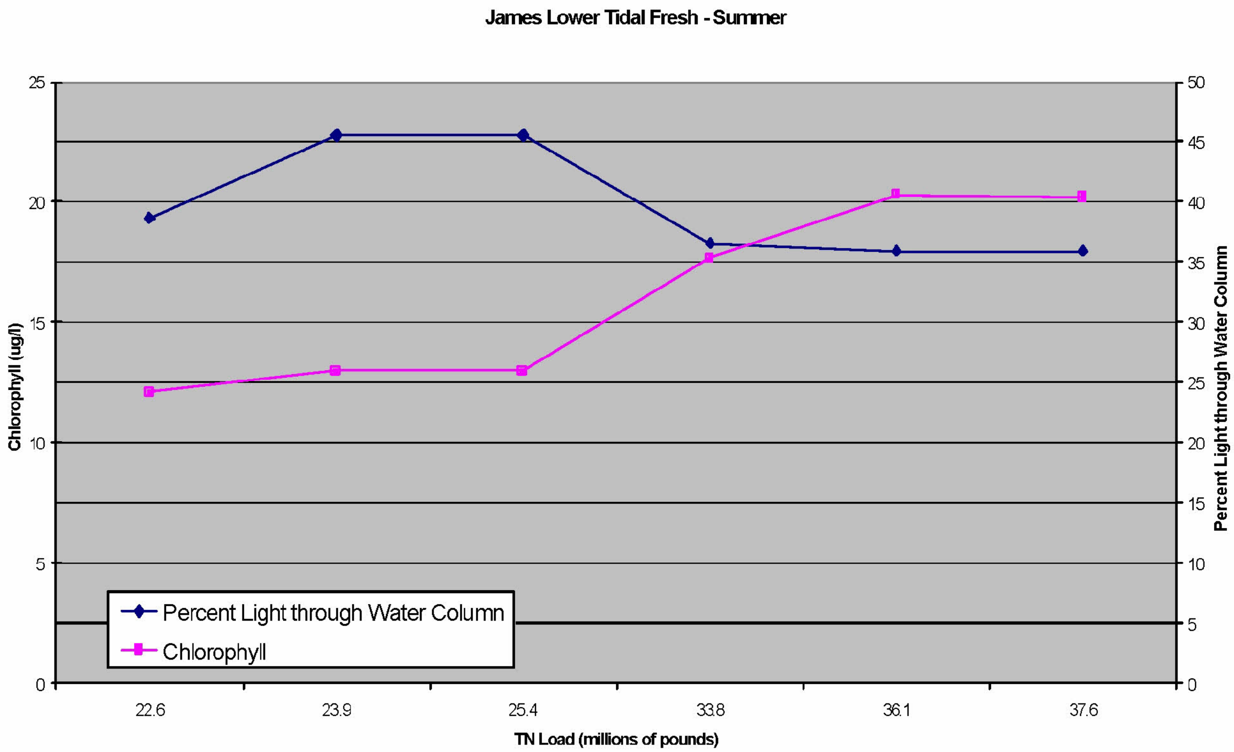
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
Scoping A	37.6	9.49	50.7
Scoping C	36.1	9.82	50.8
Scoping B	33.8	9.49	51.8
VATS	25.4	9.51	57.5
VATS Alt.	23.9	9.51	57.5
Scoping D	22.6	9.15	54.2

Figure C.33. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Lower Tidal Fresh spring period for the scoping scenarios.



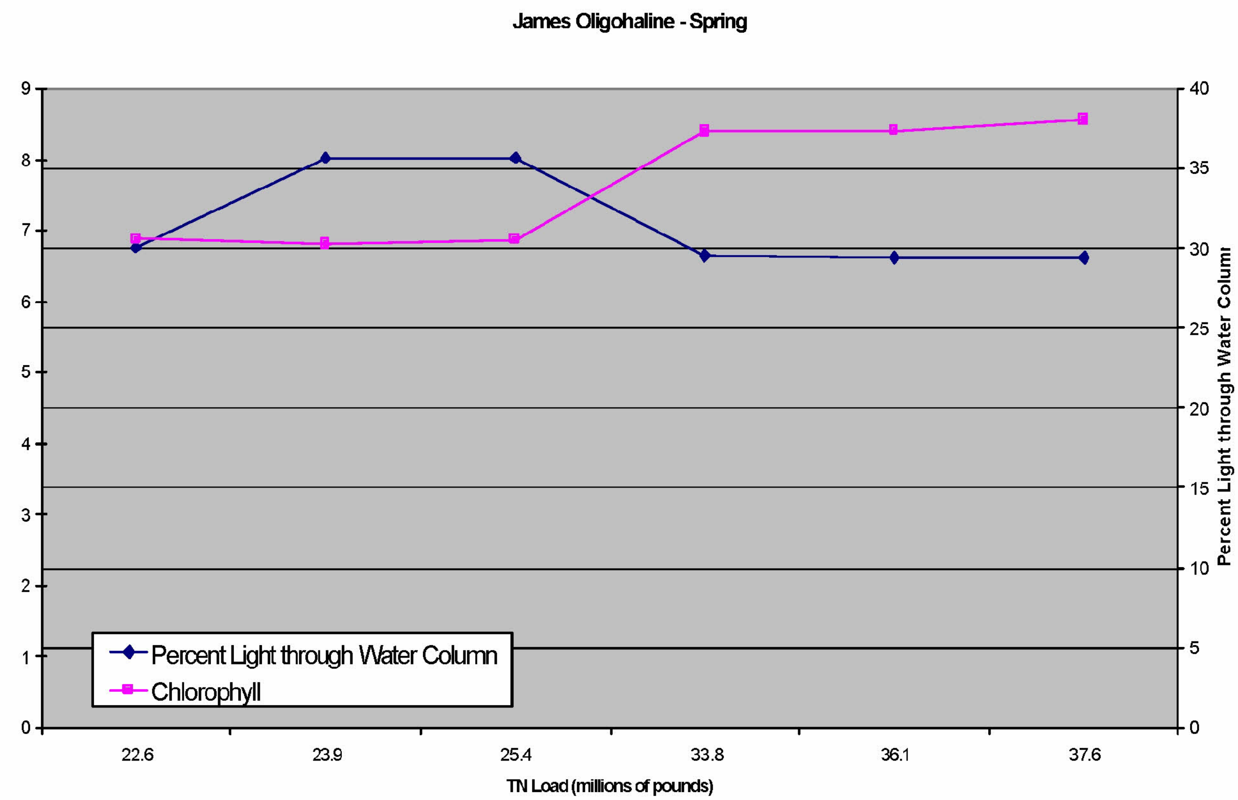
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
Scoping A	37.6	10.19	35.9
Scoping C	36.1	10.45	35.9
Scoping B	33.8	10.15	36.6
VATS	25.4	8.50	45.6
VATS Alt.	23.9	8.51	45.6
Scoping D	22.6	8.38	38.6

Figure C.34. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Lower Tidal Fresh summer period for the scoping scenarios.



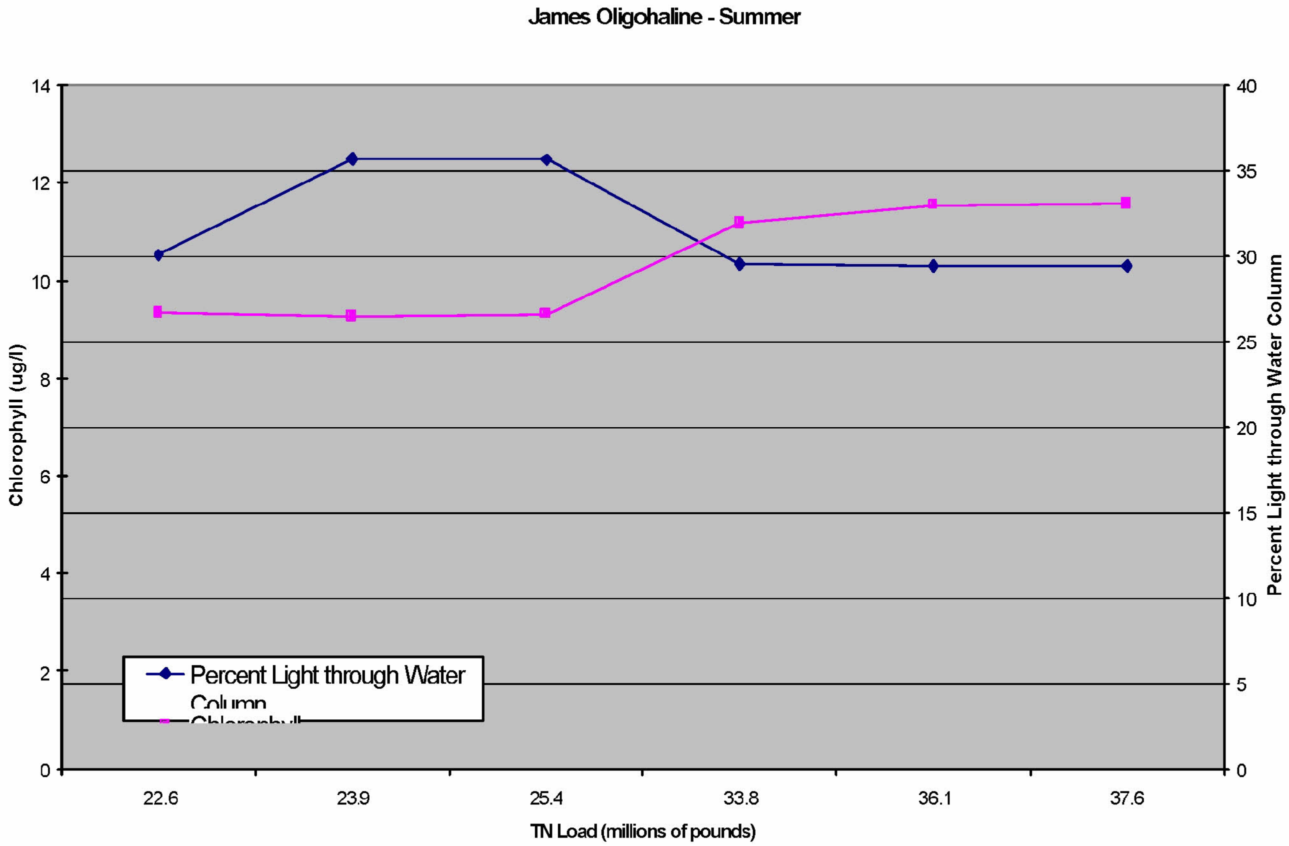
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
Scoping A	37.6	20.19	35.9
Scoping C	36.1	20.32	35.9
Scoping B	33.8	17.67	36.6
VATS	25.4	12.97	45.6
VATS Alt.	23.9	12.97	45.6
Scoping D	22.6	12.08	38.6

Figure C.35. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Oligohaline spring period for the scoping scenarios.



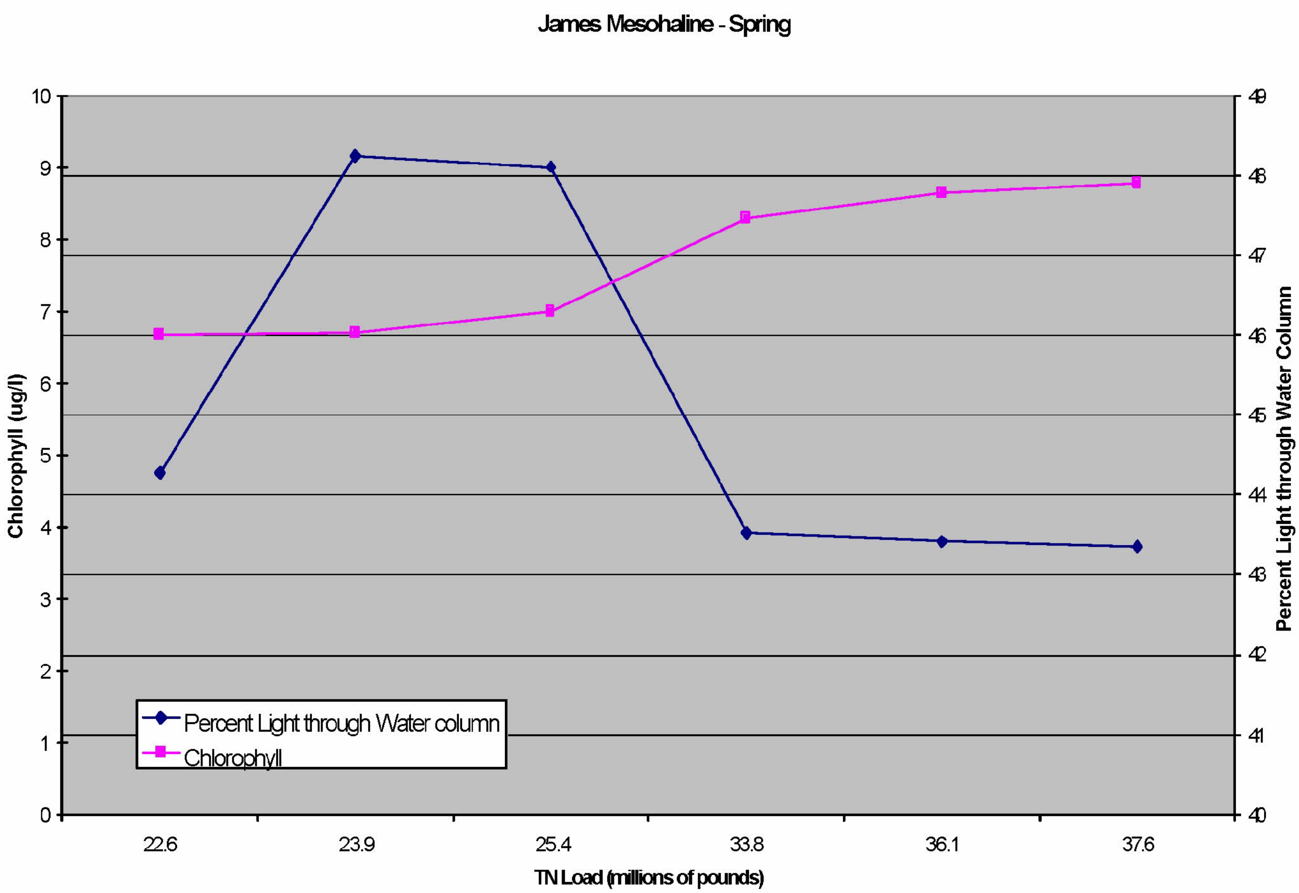
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
Scoping A	27.1	8.57	29.4
Scoping C	37.3	8.41	29.4
Scoping B	33.8	8.40	29.5
VATS	25.4	6.88	35.6
VATS Alt.	23.9	6.81	35.7
Scoping D	23	6.88	30.1

Figure C.36. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Oligohaline summer period for the scoping scenarios.



Scenario	TN Load	Chlorophyll	Percent Light in Water Column
Scoping A	37.6	11.57	29.4
Scoping B	36.1	11.55	29.4
Scoping C	33.8	11.17	29.5
VATS	25.4	9.32	35.6
VATS Alt.	23.9	9.27	35.7
Scoping D	22.6	9.35	30.1

Figure C.37. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations µg/L) and light attenuation (percent light through water) for the James Mesohaline spring period for the scoping scenarios.



Scenario	TN Load	Chlorophyll	Percent Light in Water Column
Scoping A	37.6	8.77	43.3
Scoping C	36.1	8.64	43.4
Scoping B	33.8	8.29	43.5
VATS	25.4	7.00	48.1
VATS Alt.	23.9	6.71	48.2
Scoping D	22.6	6.68	44.3

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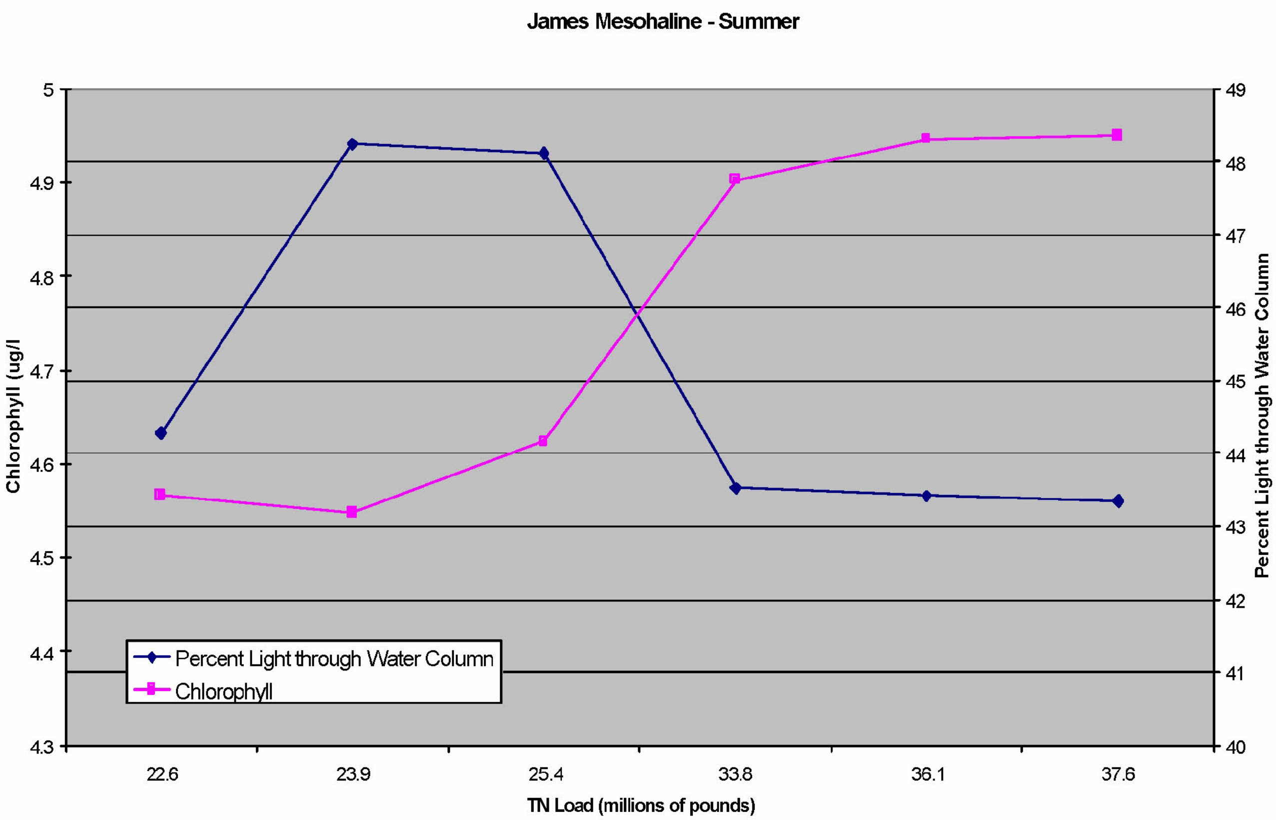
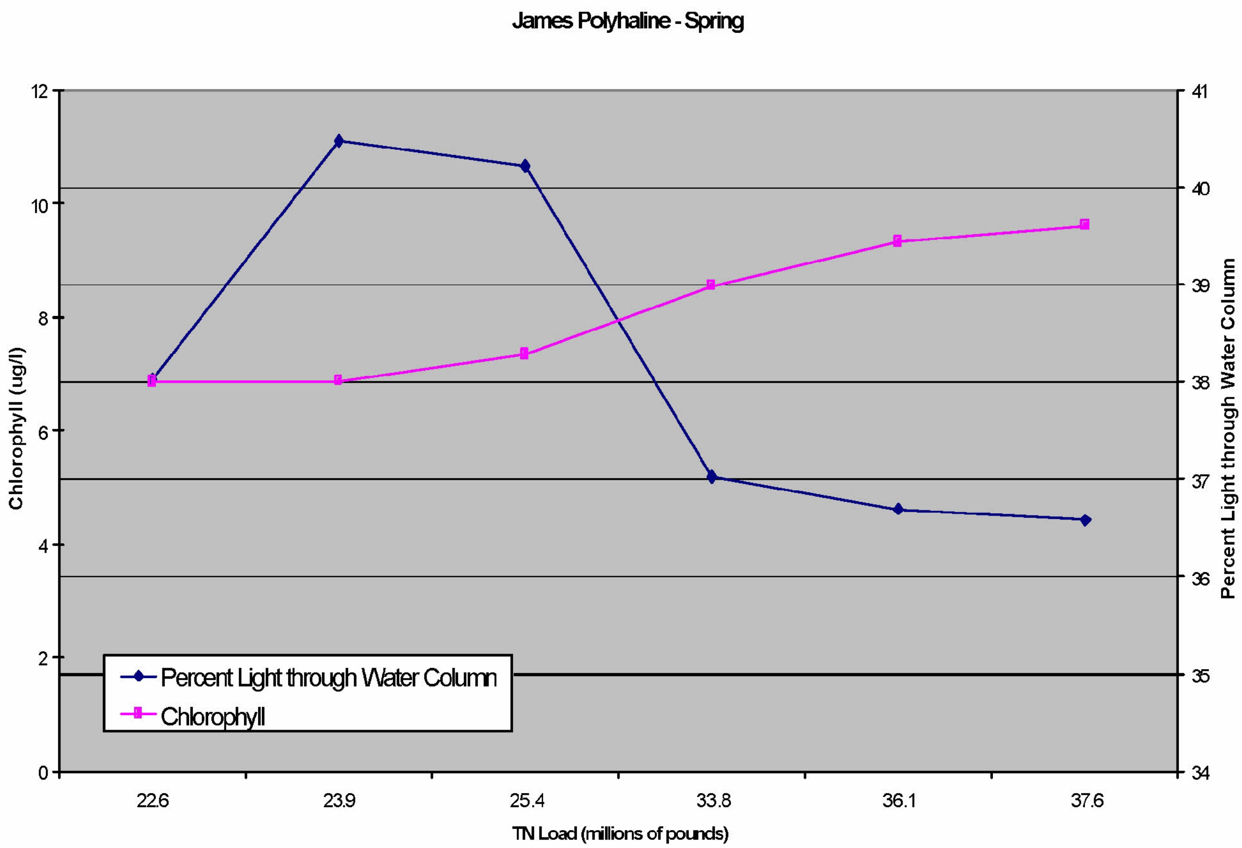
Figure C.38. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Mesohaline summer period for the scoping scenarios.



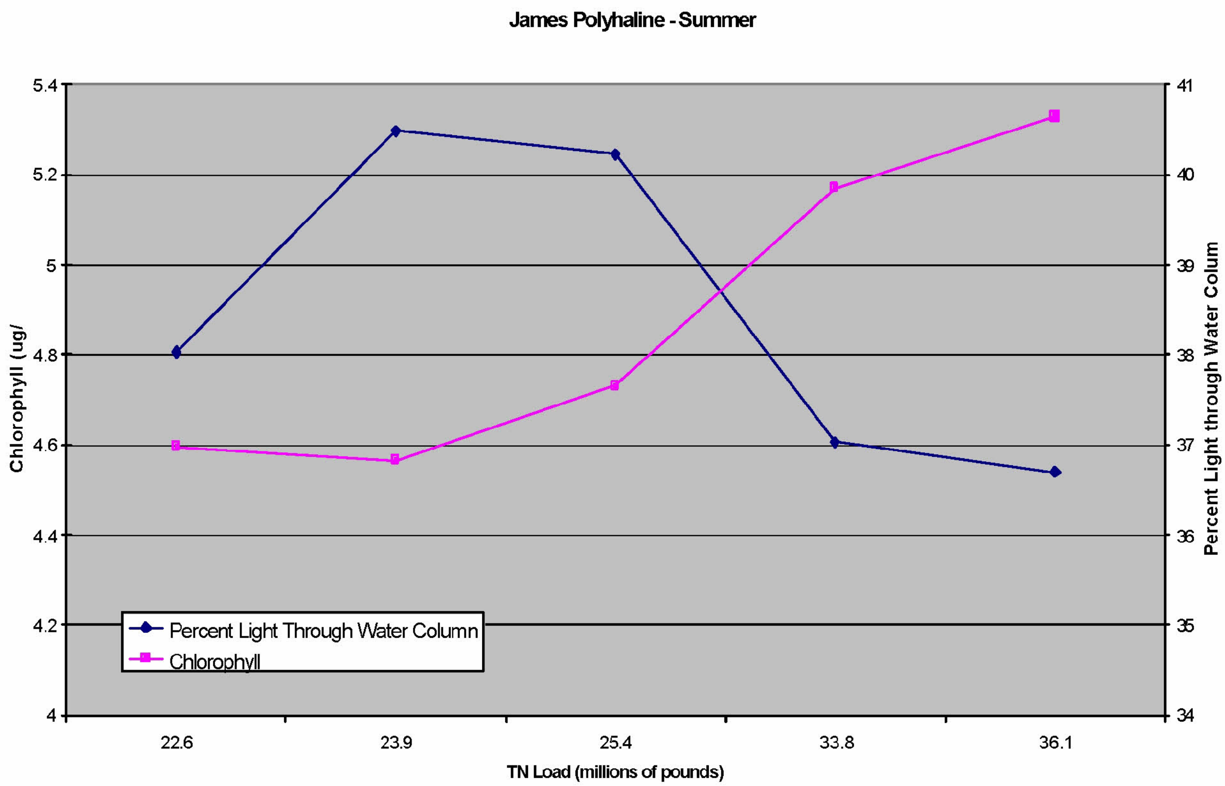
Scenario	TN Load	Chlorophyll	Percent Light in Water Column
Scoping A	37.6	4.95	43.3
Scoping C	36.1	4.95	43.4
Scoping B	33.8	4.90	43.5
VATS	25.4	4.62	48.1
VATS Alt.	23.9	4.55	48.2
Scoping D	22.6	4.57	44.3

Figure C.39. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Polyhaline spring period for the scoping scenarios.



Scenario	TN Load	Chlorophyll	Percent Light in Water Column
Scoping A	37.6	9.62	36.6
Scoping C	36.1	9.33	36.7
Scoping B	33.8	8.56	37.0
VATS	25.4	7.34	40.2
VATS Alt.	23.9	6.88	40.5
Scoping D	22.6	6.87	38.0

Figure C.40. Ten-year average total nitrogen (TN) load (million pounds) related to the model simulated seasonal average chlorophyll a concentrations (µg/L) and light attenuation (percent light through water) for the James Polyhaline summer period for the scoping scenarios.



Scenario	TN Load	Chlorophyll	Percent Light in Water Column
Scoping A	37.6	5.34	36.6
Scoping C	36.1	5.33	36.7
Scoping B	33.8	5.17	37.0
VATS	25.4	4.73	40.2
VATS Alt.	23.9	4.57	40.5
Scoping D	22.6	4.60	38.0

Table C.1. Cumulative frequency distribution (CFD) based level of attainment (A) or non-attainment (%) in time and space assuming different chlorophyll a criteria concentrations in the James Upper Tidal Fresh – Spring for all scenarios. The proposed chlorophyll a criteria for this season and river segment is highlighted.

James Upper Tidal Fresh - Spring Chlorophyll Conc. (µg/L)	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
05	44.0%	42.3%	44.0%	41.4%	28.4%	33.5%	29.2%	29.4%	4.5%	28.8%	39.0%	41.1%	25.2%
06	33.5%	23.2%	21.9%	21.7%	4.5%	27.9%	4.5%	4.5%	4.4%	4.5%	23.0%	13.9%	4.5%
07	14.0%	11.2%	13.7%	4.5%	4.4%	13.0%	4.4%	4.4%	4.3%	4.3%	4.4%	4.5%	4.4%
08	12.5%	4.1%	4.1%	4.1%	4.3%	4.5%	4.3%	4.3%	4.3%	4.1%	4.2%	4.1%	4.3%
09	4.0%	4.0%	4.0%	4.1%	4.1%	4.4%	4.1%	4.1%	3.2%	4.1%	4.1%	4.1%	4.1%
10	3.9%	3.9%	3.9%	4.0%	4.0%	4.3%	4.0%	4.0%	A	3.9%	4.0%	4.0%	4.0%
11	3.8%	3.9%	3.9%	3.9%	3.9%	4.2%	3.9%	3.9%	A	3.9%	3.9%	3.9%	3.9%
12	3.8%	3.8%	3.8%	3.8%	3.8%	4.0%	3.9%	3.9%	A	3.8%	3.9%	3.9%	3.8%
13	3.8%	3.8%	3.8%	3.8%	3.8%	3.9%	3.8%	3.8%	A	3.8%	3.8%	3.8%	3.8%
14	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	A	3.8%	3.8%	3.8%	3.8%
15	3.7%	3.7%	3.8%	3.8%	3.5%	3.8%	3.8%	3.8%	A	3.7%	3.8%	3.8%	0.4%
16	3.6%	3.6%	3.7%	3.7%	0.0%	A	3.8%	3.8%	A	3.6%	3.8%	3.8%	A
17	3.5%	3.5%	3.6%	3.6%	A	A	3.7%	3.7%	A	2.2%	3.7%	3.7%	A
18	3.2%	2.3%	3.5%	3.6%	A	A	3.6%	3.6%	A	0.4%	3.7%	3.7%	A
19	3.0%	0.2%	3.1%	3.4%	A	A	1.5%	1.5%	A	A	3.6%	3.6%	A
20	2.9%	A	1.8%	1.6%	A	A	0.3%	0.3%	A	A	3.5%	3.5%	A
21	2.3%	A	0.7%	0.1%	A	A	A	A	A	A	2.3%	3.5%	A
22	1.3%	A	A	A	A	A	A	A	A	A	0.7%	2.4%	A
23	0.4%	A	A	A	A	A	A	A	A	A	A	1.1%	A
24	A	A	A	A	A	A	A	A	A	A	A	0.1%	A
25	A	A	A	A	A	A	A	A	A	A	A	A	A
30	A	A	A	A	A	A	A	A	A	A	A	A	A
35	A	A	A	A	A	A	A	A	A	A	A	A	A
40	A	A	A	A	A	A	A	A	A	A	A	A	A
45	A	A	A	A	A	A	A	A	A	A	A	A	A
50	A	A	A	A	A	A	A	A	A	A	A	A	A

Table C.2. Cumulative frequency distribution (CFD) based level of attainment (A) or non-attainment (%) in time and space assuming different chlorophyll a criteria concentrations in the James Upper Tidal Fresh – Summer for all scenarios. The proposed chlorophyll a criteria for this season and river segment is highlighted.

James Upper Tidal Fresh - Summer Chlorophyll Conc. (µg/L)	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
05	69.0%	67.6%	66.0%	66.1%	65.0%	71.2%	66.2%	66.2%	64.5%	66.6%	65.7%	66.2%	65.0%
06	63.9%	57.7%	64.0%	61.5%	58.2%	61.2%	60.8%	60.8%	56.4%	63.8%	61.2%	64.0%	58.3%
07	60.6%	53.7%	58.4%	56.7%	54.3%	55.6%	55.0%	55.0%	50.6%	57.5%	56.3%	59.6%	54.3%
08	53.2%	48.1%	54.0%	53.1%	51.4%	54.2%	53.4%	53.4%	43.9%	53.8%	53.0%	56.0%	52.2%
09	43.1%	41.8%	47.6%	47.7%	44.6%	50.5%	48.3%	48.3%	36.3%	50.3%	48.0%	49.8%	44.2%
10	29.3%	32.7%	40.4%	40.3%	37.3%	42.6%	40.4%	40.4%	27.4%	43.3%	39.7%	42.1%	38.0%
11	19.2%	24.4%	31.2%	32.8%	28.2%	35.6%	32.5%	32.5%	20.3%	34.4%	34.5%	35.8%	27.8%
12	10.3%	19.3%	21.9%	24.0%	20.5%	25.7%	22.9%	22.9%	12.8%	24.5%	23.3%	27.5%	19.8%
13	3.6%	13.0%	13.4%	16.0%	11.2%	19.2%	14.5%	14.5%	8.0%	11.6%	16.8%	18.8%	11.0%
14	0.4%	7.0%	7.1%	7.9%	6.3%	11.7%	7.6%	7.6%	4.2%	6.0%	7.8%	10.6%	6.1%
15	0.0%	3.1%	2.8%	4.6%	3.9%	6.5%	3.3%	3.3%	0.0%	2.1%	3.7%	4.8%	1.5%
16	A	A	0.2%	1.2%	0.8%	3.3%	0.1%	0.1%	A	A	A	1.4%	A
17	A	A	A	A	A	0.5%	A	A	A	A	A	0.0%	A
18	A	A	A	A	A	A	A	A	A	A	A	A	A
19	A	A	A	A	A	A	A	A	A	A	A	A	A
20	A	A	A	A	A	A	A	A	A	A	A	A	A
21	A	A	A	A	A	A	A	A	A	A	A	A	A
22	A	A	A	A	A	A	A	A	A	A	A	A	A
23	A	A	A	A	A	A	A	A	A	A	A	A	A
24	A	A	A	A	A	A	A	A	A	A	A	A	A
25	A	A	A	A	A	A	A	A	A	A	A	A	A
30	A	A	A	A	A	A	A	A	A	A	A	A	A
35	A	A	A	A	A	A	A	A	A	A	A	A	A
40	A	A	A	A	A	A	A	A	A	A	A	A	A
45	A	A	A	A	A	A	A	A	A	A	A	A	A
50	A	A	A	A	A	A	A	A	A	A	A	A	A

Table C.3. Cumulative frequency distribution (CFD) based level of attainment (A) or non-attainment (%) in time and space assuming different chlorophyll a criteria concentrations in the James Lower Tidal Fresh – Spring for all scenarios. The proposed chlorophyll a criteria for this season and river segment is highlighted.

James Lower Tidal Fresh - Spring Chlorophyll Conc. (µg/L)	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
05	81.2%	78.0%	78.0%	78.0%	78.0%	78.0%	77.9%	77.9%	74.7%	78.0%	78.0%	78.0%	77.9%
06	78.0%	78.0%	78.0%	78.0%	74.0%	78.0%	71.6%	71.6%	59.2%	77.9%	77.9%	78.0%	71.3%
07	78.0%	78.0%	77.9%	73.9%	69.4%	72.6%	63.5%	63.5%	30.2%	73.8%	72.1%	73.8%	62.5%
08	78.0%	75.8%	75.8%	67.0%	53.5%	68.6%	47.1%	47.3%	17.3%	63.5%	64.3%	70.0%	46.3%
09	78.0%	62.6%	62.2%	52.2%	38.9%	50.8%	33.4%	33.6%	A	44.7%	50.1%	51.4%	28.7%
10	71.8%	50.3%	48.8%	40.5%	25.1%	39.4%	21.2%	21.3%	A	39.0%	38.9%	40.3%	18.7%
11	64.1%	42.7%	41.7%	30.6%	17.1%	27.8%	9.2%	9.3%	A	30.9%	29.8%	33.4%	6.8%
12	60.4%	36.4%	36.9%	22.4%	4.6%	18.6%	0.9%	1.0%	A	21.8%	21.6%	24.2%	0.9%
13	54.1%	25.2%	23.4%	12.9%	1.1%	8.4%	0.5%	0.6%	A	12.4%	10.8%	13.1%	0.8%
14	43.8%	19.0%	18.6%	2.8%	0.8%	3.1%	A	A	A	6.5%	3.3%	6.1%	0.1%
15	34.6%	12.9%	12.2%	1.2%	0.3%	0.7%	A	A	A	2.3%	1.0%	1.5%	A
16	28.2%	8.3%	6.3%	0.9%	A	A	A	A	A	0.8%	0.8%	0.9%	A
17	23.8%	4.4%	2.7%	0.8%	A	A	A	A	A	0.8%	0.8%	0.8%	A
18	21.0%	1.8%	1.6%	0.3%	A	A	A	A	A	A	0.2%	0.5%	A
19	18.4%	1.0%	0.9%	0.0%	A	A	A	A	A	A	A	0.1%	A
20	12.5%	0.9%	0.8%	A	A	A	A	A	A	A	A	A	A
21	9.8%	0.8%	0.8%	A	A	A	A	A	A	A	A	A	A
22	8.2%	0.4%	0.5%	A	A	A	A	A	A	A	A	A	A
23	6.8%	A	A	A	A	A	A	A	A	A	A	A	A
24	6.2%	A	A	A	A	A	A	A	A	A	A	A	A
25	5.8%	A	A	A	A	A	A	A	A	A	A	A	A
30	2.2%	A	A	A	A	A	A	A	A	A	A	A	A
35	0.0%	A	A	A	A	A	A	A	A	A	A	A	A
40	A	A	A	A	A	A	A	A	A	A	A	A	A
45	A	A	A	A	A	A	A	A	A	A	A	A	A
50	A	A	A	A	A	A	A	A	A	A	A	A	A

Table C.4. Cumulative frequency distribution (CFD) based level of attainment (A) or non-attainment (%) in time and space assuming different chlorophyll a criteria concentrations in the James Lower Tidal Fresh – Summer for all scenarios. The proposed chlorophyll a criteria for this season and river segment is highlighted.

James Lower Tidal Fresh - Summer Chlorophyll Conc. (µg/L)	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
05	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%
06	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.4%	86.5%	84.5%	86.8%	86.8%	86.8%	85.2%
07	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	83.7%	83.7%	83.2%	86.8%	86.8%	86.8%	83.0%
08	86.8%	86.8%	86.8%	86.8%	84.3%	84.9%	77.6%	77.7%	70.5%	86.8%	84.8%	86.8%	73.0%
09	86.8%	86.8%	86.8%	84.9%	83.5%	83.7%	71.7%	71.7%	60.0%	84.6%	83.9%	84.8%	68.0%
10	86.8%	86.8%	86.8%	84.1%	70.6%	76.6%	62.2%	62.6%	40.1%	83.9%	77.2%	84.0%	54.0%
11	86.8%	85.9%	86.1%	80.8%	64.1%	68.5%	51.8%	51.9%	27.7%	73.4%	68.5%	75.2%	45.6%
12	86.8%	82.3%	82.4%	71.7%	60.4%	63.6%	42.0%	42.1%	17.7%	69.6%	64.7%	70.3%	32.2%
13	86.8%	80.5%	80.9%	65.3%	51.3%	60.4%	34.9%	35.6%	12.7%	65.7%	60.9%	66.3%	22.5%
14	84.5%	73.7%	75.5%	62.5%	40.5%	56.8%	27.4%	27.6%	5.4%	61.9%	59.1%	62.2%	16.8%
15	83.8%	70.5%	71.7%	57.8%	33.6%	45.8%	22.1%	22.3%	2.1%	60.5%	48.3%	60.5%	14.2%
16	83.5%	67.1%	69.3%	53.2%	30.1%	39.7%	13.7%	14.1%	A	54.6%	41.6%	55.4%	11.2%
17	81.7%	64.6%	66.3%	50.6%	23.7%	36.3%	10.6%	10.9%	A	49.5%	37.5%	51.1%	6.2%
18	80.0%	58.2%	60.7%	40.9%	14.9%	33.9%	7.5%	7.6%	A	46.4%	35.6%	46.6%	4.1%
19	78.5%	54.4%	57.2%	37.5%	10.6%	27.9%	1.0%	2.2%	A	43.6%	33.5%	43.4%	0.9%
20	76.5%	52.4%	54.9%	36.1%	5.8%	20.7%	0.2%	0.2%	A	39.5%	26.6%	38.3%	A
21	71.2%	50.5%	52.3%	34.8%	0.2%	15.7%	A	A	A	35.5%	24.4%	36.1%	A
22	66.5%	48.8%	50.7%	31.4%	A	12.5%	A	A	A	32.4%	20.0%	34.0%	A
23	63.7%	46.5%	48.8%	26.5%	A	6.2%	A	A	A	29.5%	14.4%	30.1%	A
24	61.4%	40.6%	44.4%	15.4%	A	1.4%	A	A	A	24.8%	11.2%	25.2%	A
25	57.7%	36.3%	41.2%	11.0%	A	A	A	A	A	22.3%	4.8%	22.6%	A
30	46.3%	20.0%	30.2%	A	A	A	A	A	A	0.9%	A	1.3%	A
35	35.6%	1.3%	4.4%	A	A	A	A	A	A	A	A	A	A
40	19.0%	0.0%	0.9%	A	A	A	A	A	A	A	A	A	A
45	8.2%	A	A	A	A	A	A	A	A	A	A	A	A
50	5.5%	A	A	A	A	A	A	A	A	A	A	A	A

Table C.5. Cumulative frequency distribution (CFD) based level of attainment (A) or non-attainment (%) in time and space assuming different chlorophyll a criteria concentrations in the James Oligohaline – Spring for all scenarios. The proposed chlorophyll a criteria for this season and river segment is highlighted.

James Oligohaline - Spring Chlorophyll Conc. (µg/L)	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
05	73.5%	70.0%	70.0%	69.5%	67.8%	70.6%	67.0%	67.0%	64.9%	70.4%	70.1%	70.4%	67.0%
06	70.7%	67.0%	67.7%	65.0%	61.9%	60.3%	52.6%	52.6%	50.9%	59.9%	56.4%	60.0%	52.8%
07	66.9%	59.2%	59.0%	52.4%	49.5%	50.6%	46.8%	46.5%	20.7%	52.0%	51.3%	52.0%	46.9%
08	62.4%	52.0%	50.9%	48.2%	39.8%	47.4%	26.8%	24.8%	3.1%	48.0%	47.8%	47.9%	27.6%
09	57.2%	48.5%	48.0%	38.0%	22.3%	36.2%	10.1%	9.4%	A	38.8%	36.9%	37.8%	11.2%
10	53.8%	41.1%	39.7%	32.1%	9.2%	23.3%	1.7%	0.1%	A	33.2%	26.1%	28.7%	0.7%
11	46.8%	37.9%	35.5%	16.1%	1.9%	5.5%	A	A	A	14.4%	11.7%	13.4%	A
12	42.6%	27.7%	23.3%	4.7%	A	2.6%	A	A	A	3.2%	3.2%	2.9%	A
13	41.2%	20.4%	11.1%	2.3%	A	2.0%	A	A	A	2.7%	2.7%	2.3%	A
14	37.9%	5.3%	3.6%	1.0%	A	A	A	A	A	2.3%	2.2%	1.7%	A
15	31.9%	3.6%	3.0%	A	A	A	A	A	A	1.9%	1.7%	A	A
16	26.0%	3.4%	2.6%	A	A	A	A	A	A	A	A	A	A
17	21.0%	3.1%	2.3%	A	A	A	A	A	A	A	A	A	A
18	16.0%	2.8%	1.9%	A	A	A	A	A	A	A	A	A	A
19	11.6%	2.6%	0.7%	A	A	A	A	A	A	A	A	A	A
20	9.5%	2.4%	A	A	A	A	A	A	A	A	A	A	A
21	5.6%	2.1%	A	A	A	A	A	A	A	A	A	A	A
22	4.0%	1.9%	A	A	A	A	A	A	A	A	A	A	A
23	3.5%	1.2%	A	A	A	A	A	A	A	A	A	A	A
24	3.1%	A	A	A	A	A	A	A	A	A	A	A	A
25	2.8%	A	A	A	A	A	A	A	A	A	A	A	A
30	1.9%	A	A	A	A	A	A	A	A	A	A	A	A
35	A	A	A	A	A	A	A	A	A	A	A	A	A
40	A	A	A	A	A	A	A	A	A	A	A	A	A
45	A	A	A	A	A	A	A	A	A	A	A	A	A
50	A	A	A	A	A	A	A	A	A	A	A	A	A

Table C.6. Cumulative frequency distribution (CFD) based level of attainment (A) or non-attainment (%) in time and space assuming different chlorophyll a criteria concentrations in the James Oligohaline – Summer for all scenarios. The proposed chlorophyll a criteria for this season and river segment is highlighted.

James Oligohaline - Summer Chlorophyll Conc. (µg/L)	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
05	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%
06	86.8%	86.8%	86.8%	86.8%	86.8%	86.8%	78.6%	77.6%	64.0%	86.8%	86.8%	86.8%	77.4%
07	85.4%	84.8%	85.0%	82.0%	71.3%	74.0%	56.0%	55.1%	41.9%	76.9%	74.2%	76.7%	54.8%
08	80.7%	75.8%	75.6%	65.9%	51.4%	59.0%	40.5%	39.0%	18.2%	62.8%	58.8%	63.0%	39.5%
09	70.0%	60.4%	60.2%	50.3%	38.9%	44.6%	26.5%	26.1%	8.2%	46.9%	44.4%	47.3%	27.6%
10	60.8%	50.2%	50.5%	39.5%	30.0%	36.3%	10.1%	9.9%	4.7%	37.1%	36.3%	37.1%	9.9%
11	55.2%	40.5%	40.6%	31.4%	17.5%	24.7%	8.7%	8.6%	3.5%	28.9%	24.7%	27.7%	8.7%
12	46.4%	30.6%	30.9%	22.7%	9.7%	17.3%	6.9%	6.7%	3.5%	21.4%	17.2%	21.0%	6.9%
13	37.4%	24.1%	24.1%	17.1%	8.5%	10.5%	5.4%	5.3%	3.5%	16.1%	10.2%	16.0%	5.5%
14	30.8%	19.0%	18.8%	11.7%	7.2%	8.9%	4.7%	4.6%	2.8%	9.6%	9.0%	9.8%	4.8%
15	23.3%	16.0%	15.8%	8.0%	5.5%	7.7%	4.1%	4.0%	2.1%	8.8%	7.8%	8.8%	4.2%
16	18.3%	10.3%	10.4%	6.3%	4.1%	5.6%	2.3%	2.2%	1.5%	6.7%	5.9%	6.6%	2.5%
17	15.5%	7.3%	7.4%	5.1%	3.3%	4.5%	1.9%	1.9%	0.6%	5.5%	4.7%	5.4%	2.0%
18	8.5%	5.4%	5.4%	4.1%	2.6%	3.7%	1.6%	1.6%	A	4.5%	3.9%	4.4%	1.8%
19	6.0%	4.3%	4.2%	3.2%	1.8%	3.1%	1.3%	1.3%	A	3.7%	3.2%	3.6%	1.4%
20	4.0%	3.2%	3.2%	2.5%	1.1%	2.3%	0.5%	0.6%	A	3.1%	2.6%	3.0%	0.9%
21	2.7%	2.4%	2.4%	1.8%	0.4%	1.7%	A	A	A	2.4%	2.0%	2.3%	0.1%
22	1.8%	1.8%	1.8%	1.3%	A	1.0%	A	A	A	1.9%	1.4%	1.8%	A
23	0.5%	1.4%	1.4%	0.1%	A	A	A	A	A	1.3%	0.9%	1.2%	A
24	A	A	A	A	A	A	A	A	A	0.9%	0.1%	0.8%	A
25	A	A	A	A	A	A	A	A	A	A	A	A	A
30	A	A	A	A	A	A	A	A	A	A	A	A	A
35	A	A	A	A	A	A	A	A	A	A	A	A	A
40	A	A	A	A	A	A	A	A	A	A	A	A	A
45	A	A	A	A	A	A	A	A	A	A	A	A	A
50	A	A	A	A	A	A	A	A	A	A	A	A	A

Table C.7. Cumulative frequency distribution (CFD) based level of attainment (A) or non-attainment (%) in time and space assuming different chlorophyll a criteria concentrations in the James Mesohaline – Spring for all scenarios. The proposed chlorophyll a criteria for this season and river segment is highlighted.

James Mesohaline - Spring

Chlorophyll Conc. (µg/L)	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
05	77.4%	72.0%	75.6%	69.2%	61.5%	63.6%	60.5%	57.7%	46.8%	66.4%	62.9%	66.0%	52.3%
06	67.2%	56.7%	61.1%	56.2%	46.2%	46.6%	46.1%	43.9%	37.7%	54.1%	47.1%	56.3%	39.3%
07	61.5%	45.8%	49.7%	38.9%	35.3%	36.5%	34.6%	33.7%	23.4%	39.9%	36.9%	39.9%	33.6%
08	49.4%	38.5%	43.3%	34.9%	31.3%	33.5%	27.2%	24.5%	12.4%	35.6%	34.2%	35.4%	25.0%
09	44.5%	35.1%	36.4%	32.4%	23.2%	29.7%	19.3%	16.4%	0.4%	33.2%	31.7%	32.7%	17.6%
10	38.9%	33.2%	33.6%	27.9%	14.6%	20.9%	10.4%	2.5%	A	31.0%	28.5%	30.2%	6.3%
11	37.3%	30.3%	30.8%	19.3%	6.8%	15.0%	A	A	A	26.3%	18.4%	21.9%	A
12	35.2%	27.2%	27.1%	14.8%	A	9.7%	A	A	A	18.2%	13.8%	15.5%	A
13	32.6%	24.3%	22.7%	7.5%	A	A	A	A	A	12.8%	7.6%	11.5%	A
14	30.0%	17.4%	16.2%	2.1%	A	A	A	A	A	6.4%	2.9%	4.6%	A
15	27.6%	14.0%	12.0%	0.0%	A	A	A	A	A	1.7%	1.1%	1.3%	A
16	25.4%	10.3%	8.3%	A	A	A	A	A	A	A	A	A	A
17	23.0%	7.4%	3.2%	A	A	A	A	A	A	A	A	A	A
18	19.7%	3.0%	0.1%	A	A	A	A	A	A	A	A	A	A
19	14.8%	1.3%	A	A	A	A	A	A	A	A	A	A	A
20	11.5%	A	A	A	A	A	A	A	A	A	A	A	A
21	10.0%	A	A	A	A	A	A	A	A	A	A	A	A
22	9.2%	A	A	A	A	A	A	A	A	A	A	A	A
23	6.9%	A	A	A	A	A	A	A	A	A	A	A	A
24	2.9%	A	A	A	A	A	A	A	A	A	A	A	A
25	1.3%	A	A	A	A	A	A	A	A	A	A	A	A
30	A	A	A	A	A	A	A	A	A	A	A	A	A
35	A	A	A	A	A	A	A	A	A	A	A	A	A
40	A	A	A	A	A	A	A	A	A	A	A	A	A
45	A	A	A	A	A	A	A	A	A	A	A	A	A
50	A	A	A	A	A	A	A	A	A	A	A	A	A

Table C.8. Cumulative frequency distribution (CFD) based level of attainment (A) or non-attainment (%) in time and space assuming different chlorophyll a criteria concentrations in the James Mesohaline – Summer for all scenarios. The proposed chlorophyll a criteria for this season and river segment is highlighted.

James Mesohaline - Summer

Chlorophyll Conc. (µg/L)	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
05	33.5%	26.1%	26.5%	22.3%	18.6%	17.1%	9.9%	9.1%	5.5%	18.5%	17.4%	18.2%	9.4%
06	15.6%	9.6%	10.5%	7.7%	2.7%	4.5%	0.6%	0.5%	0.3%	5.5%	4.9%	5.5%	0.5%
07	6.2%	4.0%	4.1%	0.6%	0.3%	0.3%	0.2%	0.2%	0.0%	0.3%	0.3%	0.3%	0.2%
08	3.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.1%	0.1%	A	0.2%	0.2%	0.2%	0.1%
09	2.4%	0.2%	0.2%	0.2%	0.1%	0.1%	A	A	A	0.1%	0.1%	0.1%	A
10	0.2%	0.1%	0.1%	A	A	A	A	A	A	A	A	A	A
11	A	A	A	A	A	A	A	A	A	A	A	A	A
12	A	A	A	A	A	A	A	A	A	A	A	A	A
13	A	A	A	A	A	A	A	A	A	A	A	A	A
14	A	A	A	A	A	A	A	A	A	A	A	A	A
15	A	A	A	A	A	A	A	A	A	A	A	A	A
16	A	A	A	A	A	A	A	A	A	A	A	A	A
17	A	A	A	A	A	A	A	A	A	A	A	A	A
18	A	A	A	A	A	A	A	A	A	A	A	A	A
19	A	A	A	A	A	A	A	A	A	A	A	A	A
20	A	A	A	A	A	A	A	A	A	A	A	A	A
21	A	A	A	A	A	A	A	A	A	A	A	A	A
22	A	A	A	A	A	A	A	A	A	A	A	A	A
23	A	A	A	A	A	A	A	A	A	A	A	A	A
24	A	A	A	A	A	A	A	A	A	A	A	A	A
25	A	A	A	A	A	A	A	A	A	A	A	A	A
30	A	A	A	A	A	A	A	A	A	A	A	A	A
35	A	A	A	A	A	A	A	A	A	A	A	A	A
40	A	A	A	A	A	A	A	A	A	A	A	A	A
45	A	A	A	A	A	A	A	A	A	A	A	A	A
50	A	A	A	A	A	A	A	A	A	A	A	A	A

Table C.9. Cumulative frequency distribution (CFD) based level of attainment (A) or non-attainment (%) in time and space assuming different chlorophyll a criteria concentrations in the James Polyhaline – Spring for all scenarios. The proposed chlorophyll a criteria for this season and river segment is highlighted.

James Polyhaline - Spring Chlorophyll Conc. (µg/L)	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
05	86.8%	86.8%	86.8%	84.1%	76.2%	80.6%	80.7%	70.0%	59.0%	84.7%	80.2%	86.1%	67.3%
06	86.8%	84.8%	86.8%	75.5%	64.2%	65.2%	64.2%	59.5%	24.9%	76.6%	69.3%	75.5%	58.7%
07	86.8%	76.0%	82.7%	64.6%	54.6%	59.2%	53.5%	35.8%	9.7%	69.3%	62.5%	67.3%	35.3%
08	83.6%	64.5%	73.3%	57.2%	17.0%	40.0%	15.3%	11.0%	3.8%	61.1%	49.6%	58.5%	11.3%
09	78.7%	60.2%	64.5%	36.8%	9.8%	14.2%	8.2%	6.0%	A	46.3%	29.0%	42.6%	6.3%
10	72.1%	45.4%	55.4%	14.4%	5.7%	9.1%	4.0%	3.5%	A	33.0%	11.6%	28.8%	3.5%
11	59.6%	31.8%	39.9%	8.4%	3.5%	5.4%	A	A	A	11.4%	6.3%	8.8%	A
12	51.3%	16.7%	30.5%	5.5%	A	4.0%	A	A	A	6.2%	4.8%	5.6%	A
13	43.7%	10.7%	11.8%	4.3%	A	A	A	A	A	4.9%	4.0%	4.8%	A
14	35.9%	6.6%	7.1%	A	A	A	A	A	A	4.0%	A	3.9%	A
15	31.4%	5.3%	5.5%	A	A	A	A	A	A	0.2%	A	A	A
16	16.6%	4.8%	4.8%	A	A	A	A	A	A	A	A	A	A
17	10.8%	A	0.7%	A	A	A	A	A	A	A	A	A	A
18	8.2%	A	A	A	A	A	A	A	A	A	A	A	A
19	6.2%	A	A	A	A	A	A	A	A	A	A	A	A
20	5.6%	A	A	A	A	A	A	A	A	A	A	A	A
21	5.3%	A	A	A	A	A	A	A	A	A	A	A	A
22	4.8%	A	A	A	A	A	A	A	A	A	A	A	A
23	4.4%	A	A	A	A	A	A	A	A	A	A	A	A
24	A	A	A	A	A	A	A	A	A	A	A	A	A
25	A	A	A	A	A	A	A	A	A	A	A	A	A
30	A	A	A	A	A	A	A	A	A	A	A	A	A
35	A	A	A	A	A	A	A	A	A	A	A	A	A
40	A	A	A	A	A	A	A	A	A	A	A	A	A
45	A	A	A	A	A	A	A	A	A	A	A	A	A
50	A	A	A	A	A	A	A	A	A	A	A	A	A

Table C.10. Cumulative frequency distribution (CFD) based level o attainment (A) or non-attainment (%) in time and space assuming different chlorophyll a criteria concentrations in the James Polyhaline – Summer for all scenarios. The proposed chlorophyll a criteria for this season and river segment is highlighted.

James Polyhaline - Summer Chlorophyll Conc. (µg/L)	1985 Reference	2002 Assess	Tier 1	Tier 2	Tier 3	Option 4	VATS	VATS Altern.	E3	Scoping A	Scoping B	Scoping C	Scoping D
05	59.0%	51.1%	52.1%	46.9%	34.9%	38.9%	24.8%	19.4%	4.1%	43.9%	40.9%	43.9%	20.0%
06	44.0%	35.2%	38.7%	22.7%	6.4%	10.6%	2.4%	0.7%	A	19.3%	12.1%	18.8%	1.2%
07	30.0%	13.2%	16.5%	2.7%	A	0.1%	A	A	A	1.1%	0.2%	0.6%	A
08	14.7%	0.9%	2.1%	A	A	A	A	A	A	A	A	A	A
09	3.7%	A	A	A	A	A	A	A	A	A	A	A	A
10	0.0%	A	A	A	A	A	A	A	A	A	A	A	A
11	A	A	A	A	A	A	A	A	A	A	A	A	A
12	A	A	A	A	A	A	A	A	A	A	A	A	A
13	A	A	A	A	A	A	A	A	A	A	A	A	A
14	A	A	A	A	A	A	A	A	A	A	A	A	A
15	A	A	A	A	A	A	A	A	A	A	A	A	A
16	A	A	A	A	A	A	A	A	A	A	A	A	A
17	A	A	A	A	A	A	A	A	A	A	A	A	A
18	A	A	A	A	A	A	A	A	A	A	A	A	A
19	A	A	A	A	A	A	A	A	A	A	A	A	A
20	A	A	A	A	A	A	A	A	A	A	A	A	A
21	A	A	A	A	A	A	A	A	A	A	A	A	A
22	A	A	A	A	A	A	A	A	A	A	A	A	A
23	A	A	A	A	A	A	A	A	A	A	A	A	A
24	A	A	A	A	A	A	A	A	A	A	A	A	A
25	A	A	A	A	A	A	A	A	A	A	A	A	A
30	A	A	A	A	A	A	A	A	A	A	A	A	A
35	A	A	A	A	A	A	A	A	A	A	A	A	A
40	A	A	A	A	A	A	A	A	A	A	A	A	A
45	A	A	A	A	A	A	A	A	A	A	A	A	A
50	A	A	A	A	A	A	A	A	A	A	A	A	A

ATTACHMENT G

From: Bell, Clifton
Sent: Monday, January 04, 2010 3:12 PM
To: 'Lewis Linker'
Cc: 'Batiuk.Richard@epamail.epa.gov'; 'Hunley, Will'; Pomeroy, Chris
Subject: James River Chlorophyll-a Model

Lewis,

I hope you had a good holiday. Following up on the request for information on the James River chlorophyll-a model predictions: As discussed on our last call, we believe it would be valuable to create a tabular summary of observed v. model-predicted chlorophyll-*a* values and attainment rates, to determine in which segment-seasons the model predicts the correct direction and approximate relative magnitude of interannual changes in chlorophyll-a.

Attached is a CBPO table from February 2009, showing the percent non-attainment as determined from the monitoring data and the base scenario. Our understanding is that the base scenario results in this table included the data-based adjustment, and so the only reason for any differences between the observed and base scenario were differences in stations used to perform the interpolation. Ideally, we'd like to see this table reproduced to show chlorophyll-*a* means and attainment rates, without the data transformation, by three-year period and also by individual year (to help determine if wet/dry years make a difference).

We appreciate your willingness to look into this. I will call you this week just to make sure this request is clear, unless you call me first.

Clifton

PS—On slightly different but related topic: The recent Excel spreadsheets provided by CBPO show predictions of attainment by scenario (e.g., "target load scenario option 3—198 TN, 14.8 TP"). A Powerpoint presentation from the October call (attached) indicates there might be inconsistencies between the Baywide load values and the James River load values:

TN (lbs/yr)

Baywide	James
340	39
222	25.7
198	28.5
192	22.5
175	25.7
E3=?	

Can y'all please review to make sure that the James loading scenarios make sense relative to the intended progression? Regardless, it would helpful if the James River loads are indicated on the model results spreadsheets.

Clifton F. Bell, PE, PG | Malcolm Pirnie, Inc.
701 Town Center Dr., Ste. 600 Newport News, VA 23606
Office: 757-873-4465 Mobile: 757-206-9110
Fax: 757-873-8723

From: Bell, Clifton
Sent: Wednesday, June 02, 2010 5:34 PM
To: Koroncai.Robert@epamail.epa.gov; 'Batiuk.Richard@epamail.epa.gov'; 'Lewis Linker'; 'Jeni Keisman'; 'Gary Shenk'
Cc: Pomeroy, Chris; Ochsenhirt, Lisa
Subject: Information Request

CBP Modeling Team,

Good afternoon. The pace of the Bay TMDL derivation has taken off, and it appears that the Bay Program's schedule calls for very important decisions on allocations to be in a very short period of time. The V/MAMWA team understands how hard the modeling team is working to meet the schedule. We are sure that all would agree that the accelerated schedule should not compromise the technical basis of load allocations, which will have long-reaching implications. As such, we would like to request information that will help V/MAMWA and other partners evaluate and discuss the basis of load allocation to achieve D.O. and chlorophyll-*a* standards. We believe that each of the information types identified below is necessary before any decisions are made on Baywide or local allocations.

1. *<u>Information on Precision of Non-Attainment Predictions</u>*: As discussed in a recent V/MAMWA memo and on the 6/1/10 WQGIT call, we believe that the TMDL process requires a more quantitative understanding of the ability of the model and related post-processing methods to differentiate between very small non-attainment rates, and thus to differentiate between model scenarios. We understand from the 6/1/10 WQGIT call that the EPA is working on technical documentation related to the 1% rule. We request that this information be made available and explained prior to making any decisions on load allocations. We also request that this analysis not be approached as a justification of the 1% rule but as a thorough investigation of what the actual precision is, and how it might vary between model segments and across key parameters (i.e., DO and Chla). A recommended approach is a statistical power analysis of the difference in concentrations and/or non-attainment rates that could actually be confirmed as significant.

2. *<u>Investigation of Differences between Phase 5.1 and Phase 5.3</u>*: Based upon the premise that the water quality and sediment transport model (WQSTM) required little to no recalibration for use with watershed model (WSM) version 5.3, in comparison with WSM version 5.1, it is unclear why the different model versions would predict different nonattainment rates at a given loading level for some segments (e.g., CHSMH, EASMH). The answer to this question is central to understanding whether the variation in predicted attainment rates is associated with manageable variables (e.g., the geography of load reductions) versus non-manageable variables (e.g., differences in the models). It would also help better quantify the amount of nonattainment that the model can truly distinguish between model scenarios.

   We request that EPA diagnose and explain the causes of the differences in model predictions, and clearly communicate these differences to the Bay partners before basinwide targets are selected. This is most important for segments that would control either Baywide or local allocations, including CB4, EASMH, and MD5MH. It also important for segments that might not have experienced a change in load allocation, but otherwise experience a large shift in non-attainment rates between model versions (e.g., YRKMH).

3. *Investigation of Shifts in James River Allocations*: Compared to the tributary strategy scenario, the most recently proposed target loads derived from the "hockey stick" graphs include greater proposed cuts to the James River allocations than the Potomac, Patuxent, and Rappahannock Rivers combined. This appears to be illogical given the negligible influence of the James River on the mainstem Bay D.O. problem segments. We request that EPA investigate and explain the cause of this shift and the actual implications for D.O., so that the Bay partners can choose basin-specific allocations that provide meaningful water quality benefits.

4. *James River Chlorophyll-a Model Issues*: In the December 2009 teleconference on the James River chlorophyll-a issues, V/MAMWA raised questions on the WQSTM model calibration for chlorophyll-*a* in the James River. We followed this up with a written request by email dated January 4, 2010 (see below), but have not received a response. The requested evaluation is important to understanding the segments and seasons for which the model is useful for predicting chlorophyll-a attainment.

   More generally, we request that prior to recommending TMDL allocations to address chlorophyll-a, the EPA closely evaluate the reasons for non-attainment by segment-season, and make these results available to stakeholders. For example, is non-attainment in some segment seasons driven by a small number of outlier observations, or do any of the shallow water modeling issues (e.g., poor regression responses, non-intuitive model predictions) that have affected D.O. predictions also affecting chlorophyll-a predictions.

Please feel free to contact me with any questions about this information request.

Thanks,

Clifton

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From: Bell, Clifton [mailto:CBell@PIRNIE.COM]
Sent: Tuesday, July 13, 2010 10:00 AM
To: Gary Shenk; Jing Wu; Michael Barnes; Jeni Keisman
Subject: RE: Release of P5.3 download

Good morning. I was wondering if either of the following are publically available:

1. The 5.3 input decks (BMP acreages) by model scenario and major basin. I found the phase 5.2 version on the ftp site, but not the phase 5.3 version.
2. The full stoplight plots for James River chl-a attainment by model scenario, taking into account adjustments to the September 1999 data for the JMSMH Summer. All I have is a June presentation that gives stoplight plots for a limited number of scenarios.

Much appreciated.

Thanks,

Clifton

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From: Bell, Clifton
Sent: Monday, August 02, 2010 9:04 AM
To: Jeni Keisman
Cc: Aaron Gorka
Subject: James River chlorophyll-a model info

Jeni,

Good morning. While you were on vacation, I had a couple of email exchanges with Aaron on item #2 below, but it seemed that we would have to wait until your return. Do y'all have full stoplight plots for the James River, or only those shown in the June presentation? We are doing some simple cost-benefit analyses of the James, and this info would help.

Also, can you please provide the post-processing regression data for the key James River scenarios? One reason I am asking is that from the June presentation, it appears that some of the regression lines for different scenarios are plotting almost on top of one another. We'd like to determine if those regression parameters are significantly different.

Please feel free give me a call with any questions regarding this request.

Thanks,

Clifton

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ATTACHMENT H

Monitoring Data

season	CB Seg	91-'93	92-'94	93-'95	94-'96	95-'97	96-'98	97-'99	98-'00
spring:	DCATF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	DCPTF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	JMSTFL	20.3%	9.3%	10.7%	14.9%	29.2%	21.2%	37.3%	25.5%
	JMSTFU	0.9%	21.4%	20.8%	31.6%	12.0%	12.0%	1.4%	1.6%
	JMSOH	13.0%	10.9%	0.0%	10.1%	14.2%	21.9%	22.2%	32.8%
	JMSMH	34.4%	10.1%	0.0%	8.8%	26.9%	25.2%	26.3%	8.7%
	JMSPH	51.5%	26.7%	14.0%	21.8%	21.8%	21.8%	0.0%	0.0%
summer	DCATF	NoData	NoData	NoData	NoData	NoData	NoData	0.0%	0.0%
	DCPTF	21.8%	46.1%	70.9%	46.1%	46.1%	46.1%	46.1%	21.8%
	JMSTFL	56.4%	57.6%	42.2%	17.4%	23.6%	38.5%	52.8%	44.4%
	JMSTFU	27.6%	27.7%	19.6%	2.7%	16.4%	28.7%	48.4%	39.4%
	JMSOH	5.7%	5.7%	0.0%	0.0%	0.9%	0.9%	0.9%	0.0%
	JMSMH	0.0%	0.0%	0.0%	0.0%	4.9%	4.9%	29.2%	21.8%
	JMSPH	0.0%	0.0%	21.8%	46.1%	46.1%	21.8%	21.8%	46.1%

Linked Phase 5.1 and WQST Models

season	CB Seg	91-'93	92-'94	93-'95	94-'96	95-'97	96-'98	97-'99	98-'00
spring:	DCATF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	DCPTF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	JMSTFL	25.1%	13.3%	12.9%	20.6%	35.3%	27.4%	44.5%	27.6%
	JMSTFU	0.9%	21.4%	20.8%	31.6%	12.0%	12.0%	1.4%	1.6%
	JMSOH	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	2.5%
	JMSMH	34.4%	10.1%	0.0%	8.8%	26.6%	24.9%	26.0%	8.7%
	JMSPH	46.1%	21.8%	0.0%	21.8%	21.8%	21.8%	0.0%	0.0%
summer	DCATF	NoData	NoData	NoData	NoData	NoData	NoData	0.0%	0.0%
	DCPTF	21.8%	46.1%	70.9%	46.1%	46.1%	46.1%	46.1%	21.8%
	JMSTFL	52.5%	55.0%	39.4%	15.1%	19.2%	34.1%	48.1%	40.2%
	JMSTFU	27.6%	27.7%	19.6%	2.7%	16.4%	28.7%	48.4%	39.4%
	JMSOH	24.3%	19.3%	11.4%	0.3%	9.5%	13.6%	13.6%	4.5%
	JMSMH	0.0%	0.0%	0.0%	0.0%	4.9%	4.9%	29.2%	21.8%
	JMSPH	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	21.8%	21.8%

ATTACHMENT I

James River Allocations Based on Chlorophyll *a* Criteria Attainment
Summary of May 27, 2009 Conference Call

Participants: Alan Pollock, VA DEQ; Russ Perkinson, VA DCR; Clifton Belle, Malcolm Pirnie; Lisa Ochsenhirt, AquaLaw; Jim Pletl, HRSD; Will Hunley, HRSD; Beth McGee, CBF; Bob Koroncai, EPA Region 3 WPD; Rich Batiuk, EPA CBPO.

Issue: Applying the existing criteria assessment methodology, not all the tidal James River segments achieve the spring chlorophyll a criteria under E3 scenario conditions.

Possible Options (in no specific order or preference—strictly a list to work from):

1) Revisit/confirm application of the correct criteria assessment procedures;
   - Confirm we are correctly transforming the monitoring data by model output;
   - Re-evaluate the base criteria assessment procedures;
   - Re-evaluate the reference curve;
   - Address concerns about only 3 values making up the assessment curve.
2) More closely evaluate the Bay water quality/sediment transport model calibration for the tidal James River;
3) Revisit the James River chlorophyll a criteria.

Gameplan:
The following sequence of next steps were proposed and discussed during the conference call building from the above original set of options. CBPO staff will work through each step and move onto the next if the original issue can be resolved.

1) Revisit the 2005-2006 scenario results that met the draft James River chlorophyll a criteria
- Are there really different results coming out of the two respective versions of the Bay water quality model?
- What were the loads and how were those loads distributed that results in attainment back in 2005/2006 compared to now?
- Look into why CBPO used 25.7 million pounds of TN vs. 26.4 million pounds of TN listed in the 2003 Tayloe Murphy memo in running the 2003 cap scenario
- Look into P vs. N limitation in the tidal James

2) Closely evaluate the Bay water quality/sediment transport model calibration for the tidal James River
- Compare the 2009 Bay WQ/ST model vs. the 2003 Bay WQ model calibrations

3) Revisit the criteria assessment procedures and confirm we are applying procedures fully consistent with Virginia's water quality standards regulations
- Conduct a cross walk of the 2009 vs. 2003 criteria assessment procedures using Bay water quality model output focusing on what the differences between the

procedures may have lead to difference in attainment levels: use a bioreference curve vs. the 10% default curve, 10 years vs. 3 years, data transformation, etc.

- Evaluate the base criteria assessment procedures and assumptions
- Confirm the monitoring data transformed by model output steps very carefully
- Quality assurance all the criteria assessment procedure computer programming
- Review the underlying CFD plots
- Apply the prior bioreference and 10% default reference curves to see how of a difference that would make in terms of criteria attainment
- Evaluate the impact of only 3 points used to create the assessment curve

4) Revisit the development of a more appropriate biological reference curve given the advancement of the science during recent development/publication of the Bay numerical criteria

5) Re-look at the 1991-2000 hydrologic period of record for any unusual hydrologic events and whether there are any unique anomalies in the chlorophyll a record during 1991-2000.

6) Consider confidence interval around the assessment CFD curves given the collection of more spatially intensive chlorophyll a concentration data as part of the shallow-water monitoring program in the tidal James River.

7) Revisit the chlorophyll *a* criteria

- How would we apply the 2007 harmful algal bloom-based chlorophyll a criteria to the tidal James River.

Question still to be addressed: How do we select the correct three-year period for assessing criteria attainment for Bay TMDL purposes? (posed by Jim Pletl)

Next Steps:
CBPO staff will take the lead on the working through the above gameplan following Lewis Linker's well deserved vacation and the Modeling Team completes its work on the draft basinwide cap load targets for the June 22 Water Quality Steering Committee.

EPA will convene future conference calls as key findings emerge.

ATTACHMENT J

MALCOLM PIRNIE

Technical Memorandum

Date:	June 30, 2010
To:	Virginia Association of Municipal Wastewater Agencies
From:	Clifton F. Bell, Malcolm Pirnie, Inc. Will Hunley, Hampton Roads Sanitation District
Re:	Review of USEPA James River Chlorophyll-*a* Recommendations and Supporting Materials

The following technical comments are related to materials contained in the USEPA Chesapeake Bay Program's (CBP) presentation entitled "Achieving Attainment of the James Chlorophyll Water Quality Standard", dated June 18, 2010. In this presentation, EPA concludes that nutrient loadings of 23.5 TN/2.34 TP were estimated to achieve the James River chlorophyll-*a* standards. If these specified loadings were chosen as basin allocations they would result in a reduction of 4.6 TN/1.31 TP relative to the presently established tributary strategy loads of 28.1 TN/3.65 TP. However, the available technical information does not adequately support or justify nutrient reductions beyond the existing tributary strategy level for the following reasons:

- The James River chlorophyll-*a* modeling framework continues to have major technical problems including poor calibration and unexplained anomalies.
- The CBP has only partially recognized/addressed modeling problems, and has lacked clear criteria for evaluating the model accuracy, precision, and utility. The result has been a semi-arbitrary selection of which model results/data to use for load allocation or which model results to ignore.
- The predicted changes in chlorophyll-*a* (on the order of 1-2 ug/l seasonal average and 2-4% in terms of non-attainment rates) are smaller than those than can be precisely distinguished by the model, detected in monitoring data, or concluded to have ecological significance.
- Relatedly, the predicted response of chlorophyll-*a* to nutrient load reductions are extremely "flat" in key segment-seasons. Such a misapplication of the modeling framework could lead to huge expenditures without significant changes in standards attainment or result in tangible environmental improvement.

Specific comments are provided below:

1. ***The James River chlorophyll-a modeling framework has major calibration/behavior problems that have only been partially recognized and addressed***: Since December 2009, VAMWA has raised questions on the James River chlorophyll-*a* modeling calibration and utility (Bell, elec. comm., 4 Jan. 2010). Although the CBP has not specifically responded to the VAMWA's request for a detailed examination of model calibration

problem, a review of the June 18, 2010 materials indicates that the CBP has recognized certain model calibration and post-processing issues, including the following:

- Obviously erroneous calibration in certain segment-seasons (JMSTFL, JMSPH).
- Model post-processing problems as evidenced by problematic regressions used to scenario-transform the data.
- Unexplained model anomalies
- High leverage of few data in the data transformation process (e.g., September 1999 data at LE5.2).

Although these issues have been recognized for certain segment-seasons in which there were most obvious, we see no indication that the CBP has performed a more systematic review of the same issues in all segment-seasons, determined the causes/extent of model anomalies, or fully evaluated the predictive capabilities of the model. The main criteria that CBP appears to have used to deem model results as acceptable for a given segment-season appear to be:

- Whether or not the model predicts the approximate range of chlorophyll-*a*, without a systematic examination of whether the model correctly predicts the magnitude and direction of interannual *changes* in chlorophyll-*a*.
- Whether or not the model predicts decreasing chlorophyll-*a* with decreasing nutrient loads, without an examination of whether the same problems that cause counterintuitive results in some segment-seasons might also be more causing more systematic, less obvious problems in other segment-seasons.

Under the current approach, management decisions are highly susceptible to the criticism that CBP has been highly selective and partially arbitrary regarding which model predictions are usable and which are not. It would be recommended that the CBP develop a set of objective criteria for evaluating model behavior that includes: (1) a systematic evaluation of the ability of the model to quantify changes in chlorophyll-*a*; and (2) an evaluation of the causes of problem model chlorophyll-*a* predictions, and how those causes might affect the model accuracy/precision on a model global level.

2. *The predicted changes in chlorophyll-*a *are smaller than can be precisely quantified by the model.* Based on a review of the June 18, 2010 materials, CBP's justification for going beyond the 190/13 allocation level appears to be very small decreases in chlorophyll-*a* and non-attainment rates:

- 2-3% reductions in non-attainment in selected segment seasons (JMSTFL, JMSMH)
- 1-2 ug/L reduction in chlorophyll-*a* in selected segment seasons. (see Attachment A)

It is a misapplication of the model framework to claim that it is capable of distinguishing between model scenarios at these levels, or that major management decisions should be made based on these tiny predicted shifts. The precision of chlorophyll-*a* predictions can be expected to be significantly less than that for mainstem Bay dissolved oxygen (D.O.), which enjoys a much better calibration. If the model cannot distinguish between D.O. non-attainment rates of 0% and 1% (as acknowledged by CBP), the spread in distinguishable non-attainment rates for chlorophyll-*a* can be expected to be greater. Given the strong implicit margin of safety of the Bay TMDL, it cannot be concluded that model is precise enough to distinguish between scenarios that predict 0-1% nonattainment and 2-4% nonattainment.

The post-processing regression equations for the key scenarios in question might not even be significantly different. Examining the chart on the lower right of slide 12, is appears that the offset in regression equations for multiple scenarios is significantly less than the spread of data around the regression lines. (It is recommended to zoom in on the slide to visually examine the three scenario lines between the calibration and E3 scenarios). Although VAMWA did not have access to the regression data, is appears likely that statistical hypothesis testing would indicate that the parameters of these regressions are within each other's 95% confidence limits, and they are probably not even statistically distinguishable.

3. *The predicted changes in chlorophyll-*a *are smaller than could be detected in monitoring data*. It can demonstrated that tiny predicted shifts in chlorophyll-a between the 190 scenario and the "between 170/Potomac" scenario would not even be detectable in light of environmental, sampling, and analytical variability. For example:

(a) Power analysis demonstrates that even after long (25 year) monitoring periods, the minimum significant difference (MSD) in seasonal mean chlorophyll-a would be in the 2-4 ug/L range for most attaining segment seasons (Attachment B). Thus, it appears that the modeled shift in chlorophyll-*a* between the 190 and the "between 170/Potomac" scenario would probably not be detectable in the monitoring data.

(b) Based on a review of laboratory split sample results for the 1991-2000 James River data obtained from the CBMP data hub, the median relative percent difference (RPD) in chlorophyll-*a* samples was about 16 percent, corresponding to 1-4 ug/L chlorophyll-*a*, depending on segment and season (Attachment C). Thus, analytical variability alone is equal to or greater than the modeled shifts in chlorophyll-*a* between the 190 scenario and the "between 170/Potomac" scenario. Consideration of field (sampling) variability would the total variance of chlorophyll-*a* measurements to increase even further.

4. *The predicted changes in chlorophyll-*a *are not ecologically significant*. The difference in chlorophyll-*a* levels predicted between tributary strategy and the proposed reduced allocation scenarios (on the order of 1-2 ug/l seasonal average and 2-4% in terms of non-attainment rates) are exceptionally small in magnitude. This estimated level of change is too small to be seriously considered a matter of practical importance or consequence to Bay restoration. Even if the model could adequately discern such differences (which we dispute as discussed above) they would probably not result in tangible environmental

benefits. It should be remembered that the chlorophyll-*a* standard development process was acknowledged by VDEQ and stakeholders to be highly imprecise. Although its precision could not be quantified, revisions made to the criteria values on the basis of attainability were well within the differences described above. This shows that environmental conditions are essentially equivalent at the scale of a few micrograms.

VAMWA has consistently recommended that the James River chlorophyll-*a* standards eventually undergo reevaluation to take advantage of more recent monitoring data and research. It would be inappropriate to slash load allocations unless such a process clear demonstrated the ecological need.

5. *The predicted response of chlorophyll-a to nutrient load reductions are extremely "flat" in key segment-seasons*. This means that very large reductions in nutrient loading would result in only very small incremental reductions in chlorophyll-*a* concentrations and/or reductions in non-attainment rate. For example the critical segments of the tidal freshwater and lower estuary are predicted to have response rates of approximately 0.4 and 0.2 ug/l chlorophyll response per Mlb/yr TN reduction. Such a misapplication of the modeling framework could lead to huge expenditures without significant changes in standards attainment or result in tangible environmental improvement.

In previous Bay TMDL comments HRSD estimated nutrient control capital costs at $150M per mpy TN reduction. Clearly, such a misapplication of the modeling framework could lead to huge expenditures without significant changes in standards attainment or result in tangible environmental improvement.

CONCLUSIONS

Although we recognize the tight schedule for the Baywide TMDL, we do not believe it is the best interests of Virginia or the environment to make large cuts to allocations on the basis of near non-detectable shifts in chlorophyll-*a* predicted by a problematic, imprecise model. It is recommended that TMDL allocations for the James River be based on the 191/14.4 (Tributary Strategy) scenario, and that Virginia initiate a longer-term process for reevaluating and refining the modeling framework, chlorophyll-*a* standards, and load allocations as necessary.

ATTACHMENT A
Estimation of the Magnitude of Model-Predicted Changes in Chlorophyll-*a*

This attachment describes how the CBP presentation entitled "Achieving Attainment of the James Chlorophyll Water Quality Standard" (dated June 18, 2010) was used to interpret the magnitude of predicted changes in seasonal average chlorophyll-*a* between the 190/12.7 scenario and the "between 170/Potomac" scenario. VAMWA did not have access direct access to model output or post-processing regression equations for most segments and months. Therefore, the approximate magnitude of the shift was estimated by examination of regression relationships for key segment-months:

- JMSTFL April 1995 (slide 6), taken as representative of JMSTF Spring
- JMSMH September 1999 (slide 12), taken as representative of JMSTF Summer

The offsets in predicted ln_chla between regression lines for different scenarios were quantified as a function of decreases in the James River total nitrogen load. These demonstrated an approximately linear relation between ln_chla and TN load, with the following approximate slopes:

- JMSTFL Spring: 5.72E-2 reduction in ln_chla for every 1 Mlb/yr TN reduction in the James River TN load.
- JMSMH Summer: 3.37E-2 reduction in ln_chla for every 1 Mlb/yr TN reduction in the James River TN load

The "between 170/Potomac" scenario represents a 3.1 Mlb/yr reduction in James River TN load, relative to the 190 scenario. This corresponds to the following predicted reductions in ln_chla:

- JMSTFL Spring: 0.177 reduction in ln_chla.
- JMSMH Summer: 0.104 reduction in ln_chla

As these JMSTF-Spring and JMSMH-Summer approach attainment with the existing chlorophyll-*a* criteria, their seasonal average chlorophyll-a values will approach 15 ug/L and 10 ug/L, respectively. At these levels, the predicted reduction in ln-chla listed above would correspond to the following reductions in chlorophyll-a concentration:

- JMSTFL Spring: ~2 ug/L reduction in chlorophyll-*a*
- JMSMH Summer: ~1 ug/L reduction in chlorophyll-*a*

ATTACHMENT B
Power Analysis of Seasonal Mean Chlorophyll-*a*

A two-sample power analysis was conducted to determine the minimum significant difference (MSD) in the seasonal mean chlorophyll-*a* concentrations that could be expected in the James River, Virginia. Values of α and β were set to conventional values of 0.05 and 0.2, respectively. The value of n was selected as 25, representing the approximate number of years for which a pre-TMDL seasonal mean could be calculated for most James River segments, and also representing a 25-year post-TMDL monitoring period.

In order to determine the standard deviation of the chlorophyll-a seasonal means, 1991-2000 monitoring data were obtained from the CBMP data hub. Seasonal means were calculated simple as the mean of all surface layer chlorophyll-*a* values by segment and season (spring & summer). These seasonal mean values were compared to water quality criteria. Standard deviations were calculated for segment-seasons for which the seasonal mean values were below the criteria (Table A.1). This represents a simplification of the full CFD-based assessment process, but was conducted to identify the approximate standard deviations of seasonal mean chlorophyll-a values in segment-seasons that are likely to be in attainment.

TABLE A.1—Standard Deviation of Seasonal Mean Chlorophyll-*a*, 1991-2000

Season	JMSMH	JMSOH	JMSPH	JMSTF1	JMSTF2
Spring	2.8	4.5	2.4	4.1	2.1
Summer	2.3	3.7	1.9	4.2	3.9

The power analysis was conducted using the software of Lenth (2010). Result (Table A.2) indicate that the MSD in seasonal mean chlorophyll-*a* is 2-4 ug/L for most attainment segment-seasons.

TABLE A.2—Minimum Significant Difference in Seasonal Mean Chlorophyll-*a*

Season	JMSMH	JMSOH	JMSPH	JMSTF1	JMSTF2
Spring	2.3	3.7	1.9	3.3	1.7
Summer	1.9	3.0	1.5	3.4	3.2

ATTACHMENT C
Relative Percent Difference of Chlorophyll-*a* Measurements

The relative percent difference (RPD) of chlorophyll-*a* lab splits were calculated from 1991-200 James River data obtained from the CBMP data hub. An RPD was calculated for each sampling event for which chlorophyll-*a* data were reported for both "S1/LS1" and "S1/LS2" sample types. RPD was calculated using the following equation:

$$RPD = \left|\frac{x_1 - x_2}{(x_1 + x_2)/2}\right| \times 100$$

A total of 595 data pairs were available for the calculation. The mean RPD was 35%, but this value was strongly affected by outliers. The median RPD was 16%. There was no obvious graphical trend in RPD with chlorophyll-*a* magnitude.

cfb